

**Evidence for Negative Priming**  
**in**  
**Children**

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# TABLE OF CONTENTS

	Page Number
<b>List of Tables.....</b>	<b>3</b>
<b>List of Figures.....</b>	<b>4</b>
<b>Abstract.....</b>	<b>5</b>
<b>1.0 INTRODUCTION.....</b>	<b>6</b>
1.1 Negative Priming Paradigms	6
1.2 Selective Attention Studies with Children	8
1.3 Mechanisms of Selective Attention in Children Using Negative Priming Tasks (Tipper et al., 1989 versus Simone & McCormick, 1999)	12
<b>2.0 EXPERIMENTS 1 AND 2.....</b>	<b>23</b>
2.1 Conceptual NP in Children Using a Non-Spatial Task: Theoretical and Contextual Considerations	24
2.1.1 Inhibition as a Source of NP	24
2.1.2 Maximizing Attentional Selectivity	29
2.2 Experiment 1 - The Colour Blob Task	32
2.2.1 Method	34
2.2.2 Results	38
2.3 Discussion	41
2.3.1 NP Effects in Children	41
2.4 Experiment 2 - Stroop Colour-Naming Task	43
2.4.1 Method	44
2.4.2 Results	46
2.5 Discussion	49
2.5.1 Developmental Trends with the Stroop Effect	50

2.5.2 Mechanisms of Selective Attention	52
<b>3.0 EXPERIMENT 3.....</b>	<b>53</b>
3.1 NP as an Index of Implicit Memory: Effects with Novel Possible and Impossible 3-D Shapes	54
3.1.1 Implicit Memory	54
3.1.2 Implicit Memory for Novel Possible and Impossible 3-D Shapes	54
3.1.3 NP Effects With Novel Items and Possible And Impossible 3-D Shapes	55
3.1.4 Short- and Long-Term NP Effects for Novel Possible and Impossible 3-D Shapes	57
3.2 Experiment 3: Short- and Long-Term NP Effects For Novel Possible and Impossible 3-D Shapes	60
3.2.1 Method	61
3.2.2 Results	66
3.3 Discussion	70
3.3.1 Long-Term NP Effects	70
<b>4.0 GENERAL DISCUSSION.....</b>	<b>72</b>
4.1 Implications for Inhibitory Processing and the Ability to Attend Selectively in Children	73
4.2 Age and Inhibition	74
<b>5.0 REFERENCES.....</b>	<b>77</b>
<b>6.0 APPENDICES.....</b>	<b>86</b>

## LIST OF TABLES

	Page Number
Table 2.2.1	Mean Reaction Times (in Milliseconds) and Percentage of Errors for each Age group as a Function of Priming Condition in Experiment 1
	38
Table 2.2.2	Percentage of Participants showing NP Effects in Experiment 1
	40
Table 2.4.1	Mean Reaction Times (in Milliseconds) and Percentage of Errors for each Age Group as a Function of Priming Condition in Experiment 2
	46
Table 2.4.2	Percentage of Participants showing NP Effects in Experiment 2
	48
Table 3.2.1	Means of Medium Reaction Times (in Milliseconds) and Percentage of Errors for each Age Group as a Function of Priming Condition in the Immediate Condition in Experiment 3
	66
Table 3.2.2	Percentage of Participants showing NP effects in Experiment 3: Immediate Condition
	68

## LIST OF FIGURES

	Page Number
Figure 2.2.1. Experiment 1: Control versus IR main effect.	39
Figure 2.2.2. Experiment 1: NP effect as a function of age group * $p < .001$ .	40
Figure 2.4.1. Experiment 2: Control versus IR main effect.	48
Figure 2.4.2. Experiment 2: NP effect as a function of age * $p < .001$ .	48
Figure 3.2.1. Sample of possible and impossible 3-D shapes used in Experiment 3. Adopted from Neumann (1999).	63
Figure 3.2.2. Example of a "same-different" IR prime-probe trial used in Experiment 3. Adopted from Neumann (1999).	63
Figure 3.2.3. Sequence and timing of a trial's events. Adopted from Neumann (1999).	66
Figure 3.2.4. Experiment 3 immediate condition: Control versus IR main effect.	67
Figure 3.2.5. Experiment 3 lag condition 11 - 12 yr olds: Control versus IR main effect.	69

## **Abstract**

Tracking the fate of irrelevant information using the negative priming paradigm may provide valuable insight into mechanisms underlying selective attention. Negative priming effects may reflect efficient inhibitory function acting to facilitate selection of relevant information (e.g., Tipper, 1985). Although negative priming effects are consistently observed in young adults, their existence in children is questionable (Simone & McCormick, 1999; Tipper, Bourque, Anderson, & Brehaut, 1989). This study addressed the question of whether children would show negative priming in conceptual and identity-based experimental designs. Three experiments were used to examine inhibitory function in children aged five to 12 years. It was argued that negative priming effects in children may be determined by factors within the experimental context affecting selection requirements across prime and probe trials. Specifically, negative priming effects in children may be absent when selection difficulty is reduced or expectation of selection difficulty is not upheld across experimental trials. Experiments 1, 2, and 3 attempted to maximise and maintain selection difficulty across prime and probe trials by omitting any repeated distractor conditions, employing only the relevant Ignored Repetition and Control conditions, reducing spatial separation between target and distractor, downplaying the saliency of Ignored Repetition manipulation, and using overlapping stimuli. Because the results of these experiments produced significant and similar magnitudes of negative priming across the tested age range, it appears that inhibitory capacity is intact and operational by the age of five. The results were quite consistent in each of the three experiments. They were found with both naming and same-different matching paradigms, vocal and manual responses, familiar and unfamiliar stimuli, and three-dimensional possible and impossible shapes. Taken together, these findings, coupled with increasing evidence for negative priming in older adults, strongly suggested that inhibitory processing capacity is intact across the life-span.

## 1.0 INTRODUCTION

Selective attention involves an ability to focus on stimuli relevant to the task at hand. An understanding of the processes modulating selective attention is a critical prerequisite to the understanding of human cognition. In a world where visual stimuli are virtually limitless, efficient visual selective attention abilities are likely to be fundamentally important at all ages. Effective interactions with such a world undoubtedly depend, at least in part, on efficient selection of relevant from irrelevant material.

Investigating the mechanisms underlying selective attention has become an area generating considerable theoretical and empirical interest. An emerging view in the literature on selective attention is that selection of target stimuli is accomplished in part by inhibitory processes acting on simultaneously presented non-target stimuli. As detailed below, the cognitive consequence of this process is often negative priming (see Tipper, 2001, for a recent review).

### *1.1 Negative Priming Paradigms*

Negative priming (NP) is a term coined by Tipper (1985). It refers to the finding that when a stimulus is ignored subsequent response to that stimulus is typically slowed or less accurate. This phenomenon is demonstrable through a series of paired trials, each trial containing a specified target and distractor. Collectively referred to as couplets, the first of these trials is termed the prime trial, and the second the probe trial. Generally, both of these trials consist of two stimuli, one functioning as the target to be attended and the other as the distractor to be ignored. If a distractor in the prime trial becomes a target in the probe trial, a condition known as an ignored repetition (IR) couplet, the



response made to this target by the subject is usually slowed, relative to response to control couplets where prime distractor and probe target are unrelated. This increase in reaction time in IR trials is known as NP and is reliably demonstrated by young adults participating in a variety of negative priming tasks employing a wide range of stimuli such as pictures, letters, words, Stroop items, and novel shapes (Lowe, 1985; Neumann, 1999; Tipper, 1985; Tipper & Cranston, 1985; Tipper & Driver, 1988; Treisman & DeSchepper, 1996; Yee, 1991).

NP effects may provide a window into the processes involved in attentional selection. A number of researchers argue that the NP effects observable in IR couplets are caused by inhibitory processes associated with the distractor on the prime trial (Houghton & Tipper, 1994; May, Kane, & Hasher, 1995; Tipper & Cranston, 1985; Tipper, 1985). From this perspective, inhibition functions to enhance response to the target by reducing interference from the distractor. The inhibition of the prime distractor then has down-stream repercussions causing a delay if that stimulus, or a related stimulus, appears as a target in a subsequent probe trial. Inhibition-based theories of NP propose that the occurrence of negative priming should be taken as evidence " ... that information that is momentarily irrelevant and distracting is actively inhibited as a function of target selection" (Neumann, McCloskey, & Felio, 1999, p.1052). A number of researchers have, in fact, presented compelling evidence to suggest that distractor inhibition underlies NP effects (e.g., Houghton & Tipper, 1994; Neumann & DeSchepper, 1991; Neumann et al., 1999; Tipper, 2001).

A noticeable deficiency in this particular area of cognitive psychology is the paucity of studies concerned with the development of selective attention and its mechanisms. Although much research has reliably demonstrated NP in adults, there is little evidence concerning its development or even its existence in children. In fact, only two studies (Simone & McCormick, 1999; Tipper, Bourque, Anderson, & Brehaut, 1989) have used NP paradigms to investigate the development of mechanisms of attention in

children. Moreover, the results from these two studies are contradictory. Such disparity does not allow for clear-cut conclusions to be drawn regarding the ability of children to inhibit distracting information. Further empirical research is thus required before theoretical advancement can be made in this area. By measuring cognitive processes potentially important for effective attentional processing, the NP paradigm can make a considerable contribution to the understanding of cognitive development.

The present study is devoted to investigating the development of conceptual (i.e., identity or semantic) NP effects in children from age five to 12. The sections that follow provide: 1) a brief synopsis of the existing developmental literature on selective attention with particular reference to work suggesting that the ability of young children to attend selectively is hampered by an inherent susceptibility to distraction; 2) a review of research by Tipper et al. (1989) who in attempting to isolate the basis of this interference through a NP task, found selectivity in children to be compromised by a diminished ability to inhibit irrelevant information; 3) a review of the work by Simone and McCormick (1999) whose demonstration of intact identity NP in children questions the reliability of Tipper et al.'s (1989) findings. Because they provide much of the motivation for the present experiments, a summary of the discrepancy between these studies and their implications will then follow.

### ***1.2 Selective Attention Studies With Children***

The development of visual selectivity occurs early in life. During the first two to three months of life neural system development allows for a number of changes in selectivity. Initially it is intensity of stimulation that determines the direction of newborns' looking. This is largely attributed to immaturity in the peripheral and central components of the visual system and in the central nervous system (Banks & Ginsburg, 1985; Graham, Anthony, & Ziegler, 1983; see Ruff & Rothbart, 1996, for a review). After the age of two months the direction of looking in the infant is less likely to be determined by intensity of stimulation. Instead, the infant demonstrates improving perception and

recognition of more complex patterns as control over eye movements increases along with coordination between orienting and attention. Johnson (1990) attributes these changes to the development of the outer layers of the visual cortex. By the age of one month development of a pathway from the basal ganglia to the superior colliculus occurs. This provides inhibitory control over eye movements thus allowing for some visual selectivity over aspects of external events previously tending to induce automatic ocular activity. By four months of age a pathway linking the frontal eye fields to the superior colliculus and the parietal cortex develops which permits additional control of selectivity by cognitive and experiential factors.

Most studies tracking the course of attentional selectivity in children have focused on developmental differences in susceptibility to distraction. Up to now, little emphasis has been placed on the medium of selectivity. Instead, a large amount of research has been dedicated to the developmental course of attentional processes ranging from work with filtering tasks to studies dealing with performance on "executive" tasks. An overview of these studies reveals that the performance of young children is affected more than that of older children or adults when irrelevant information is present. A few illustrative examples and their implications are discussed below.

Assessment of the ability to "filter out" irrelevant information has been investigated in a variety of contexts including: selective listening, same/different judgments, Stroop, incidental learning, and speeded classification tasks. Selective listening tasks require the subject to repeat words spoken by one voice in the presence of a second irrelevant and potentially distracting voice. Retention of, and intrusions from, the irrelevant voice was found to lessen between the ages of eight and 14 years. This improvement in performance was suggested to reflect an increasingly effective ability to resist and ignore intrusions from the distracting material (Doyle, 1973, reviewed in Dempster, 1995). Doyle concluded that the ability to "filter out" irrelevant information before it is processed to the level of meaning improves with age.

Performance on same/different judgement tasks and speeded classification tasks require maintenance of attention while separating relevant from irrelevant information. Similar to findings involving selective listening, selective sorting of relevant information was found to improve with age. Stroop tasks require participants to identify the ink colour in which a word is written while ignoring the identity of the word itself. As word processing is a highly automatized skill (MacLeod, 1991), response in the Stroop task is particularly difficult when the word itself names a colour that is different from colour of its print (e.g., the word "GREEN" in red ink). In this situation, semantic representations associated with the colour that the word names become automatically activated during the process of naming the ink colour. Inadvertent contributions from this automatized word processing are evident from two sources. Compared to neutral trials in which participants name colour patches, words paired with incongruent ink colours impair performance. Attentional selection in the Stroop task is required to ensure that responding is directed to the task-relevant processing of ink colour rather than to the task irrelevant processes associated with the word's identity. Children below reading age are not likely to be susceptible to intrusion from inadvertant word processing in the Stroop task. However, once word processing has become automatized, children's responses in this task are typically delayed, relative to adult subjects, demonstrating larger intrusion effects from irrelevant distractors (Comalli, Wapner, & Werner 1962). Results from studies using incidental learning tasks also support these observations. Incidental learning refers to a tendency to accumulate and retain irrelevant information during a specified task. The basic proposition behind the incidental learning paradigm is that the more a person is able to focus on the relevant aspects of a particular task or stimulus, the less they will remember about any irrelevant aspects involved. A number of studies have shown that the amount of such incidental learning decreases with age (Siegal & Stevenson, 1966).

Developmental studies examining executive function also parallel the age-related improvements noted with filtering tasks. Executive function is a term widely used to

define a number of processes involved in complex goal-directed behaviour. Included amongst a typical list of executive functions are interference and attentional control, both levelled at the ability to ignore and block irrelevant response (Roberts & Pennington, 1996). As with filtering tasks, effective performance on executive tasks demands the ability to screen out, or in some way eliminate or reduce, intrusion from task-irrelevant information. Research undertaken by Welsh, Pennington, and Groisser (1991) into normative-developmental performance on a number of executive function tasks found that a number of different executive competencies develop at different times. Tasks tapping resistance to interference and the ability to control irrelevant response were found to mature later in development. A common measure of these functions is the Matching Familiar Figures Task (Kagen, 1965), a task which requires participants to match a target stimulus to one of six other drawings, all but one of which vary in some small detail from the example. The dependent measures are total number of errors and time to the first response. Children under the age of ten are typically inaccurate, responding too quickly with an error rate almost double that for 11 to 12 year old children.

Lane and Pearson (1982) suggested that more emphasis be placed on the manner in which irrelevant stimuli cause interference rather than on tracking children's susceptibility to interference. They proposed that an examination of the mechanisms underlying developmental differences in performance would be of value in guiding future research on attention. The principal study to take up this line of inquiry in children was by Tipper, Bourque, Anderson, and Brehaut (1989) who used a NP paradigm in an attempt to account for the developmental differences in interference sensitive tasks.

Because the NP effect is commonly viewed as an operational benchmark for efficient inhibitory functioning, a large number of researchers have begun using NP as an index of inhibitory functioning in special populations known to have selection difficulties or

tending towards suboptimal cognitive performance. For example, NP effects have been evaluated for older adults (Hasher, Stoltzfus, Zacks, & Rypma, 1991); schizophrenic patients (Laplante, Everett, & Thomas, 1992); and schizotypal persons (Ferraro & Okerlund, 1996). Little or no difference between Control and IR trial response times in these populations have been taken to imply a diminished ability to inhibit distracting information, a deficiency which could account for observable variability in cognitive performance.

### ***1.3 Mechanisms of Selective Attention in Children Using Negative Priming Tasks (Tipper et al., 1989 versus Simone & McCormick, 1999)***

Tipper et al. (1989) proposed that children's greater susceptibility to distractor intrusion and interference may be explained by weakened inhibitory capacity. Preliminary support for this contention came from research with adults by Tipper and Baylis (1987) comparing levels of NP with individual scores on the Cognitive Failure Questionnaire (Broadbent, Cooper, Fitzgerald, & Parks, 1982). The Cognitive Failure Questionnaire (CFQ) is an index of failures in attention in everyday situations. High scores in the CFQ correspond to greater tendency toward attentional failure. Participants in Tipper and Baylis study who scored high in the CFQ demonstrated less evidence for inhibition as observed through NP than those with lower scores. Accordingly, Tipper and Baylis concluded that efficiency of the distractor inhibition mechanism has direct consequences for the efficiency of selective attention.

Much of the following section is dedicated to reviewing the particular methodology employed by Tipper et al. (1989). A detailed description of the experimental conditions and various manipulations that were used in both of the experiments reported in that article is warranted because, as will be seen, it becomes highly relevant in later discussion.

The first of Tipper et al.'s (1989) NP experiments used a variant of the Stroop task to test the prediction that children should demonstrate less negative priming than adults

due an immature ability to inhibit potentially distracting material efficiently. Participants in the study included children (7 - 8 years) and adults (19 - 21 years). In addition, this experiment was also designed to observe the relationship between NP and repeated distractor effects. In the repeated distractor condition the same nontarget distractor stimulus is used repeatedly trial after trial and leads to a speed-up in responding, compared to control trials. Both manipulations were included in an effort to differentiate between two competing explanations (habituation and inhibition) for repeated distractor facilitation.

Responses to target stimuli are facilitated when distractor stimuli are repetitive rather than changing. This phenomenon has been demonstrated in a number of studies with adult participants through the use of Repeated Distractor trials (i.e., Lowe, 1979; Pomerantz & Garner, 1973; Rabbitt, 1967; Tipper & Cranston, 1985; Tipper, 1984; reviewed in Tipper et al., 1989). However, there are two competing explanations for this effect. The first of these involves the mechanism of habituation. Habituation, according to Sokolov (1963), is observed through research procedures whereby the repetitive presentation of identical stimuli results in the lessening of the orienting reflex (an automatic response typically elicited by the occurrence of novel stimuli). This suggests that responses to target stimuli should be facilitated when distractor stimuli are repetitive rather than changing.

A second explanation for repeated distractor facilitation favours the mechanism of inhibition. Tipper and Cranston (1985) initially argued that the mechanism underlying repeated distractor facilitation is the same as that underlying NP effects. Inhibitory mechanisms act to suppress competing and distracting information during target selection. As a consequence of this operation, inhibition becomes associated with the distractor stimulus causing a delay in response should it reappear as a target (Tipper, 1985). For the same reason, however, if a distractor is repeatedly presented as a distractor it is likely to be continuously inhibited, and less interfering. As a

consequence, the ability of the distractor to intrude on target processing declines and thus target selection is enhanced.

Facilitated performance in situations where distractor stimuli are repetitive may therefore be explained by two opposing hypotheses. Consider the following scenario involving Stroop stimuli. The habituation hypothesis predicts that repeated presentation of the word "RED" (distractor) in a Repeated Distractor test condition would facilitate response to the target (differing print colours of the word "RED"). This effect could be due to the habituation of the orienting response to the distractor. As the word "RED" would rapidly cease eliciting an orienting reflex, the result would be a decreased response time in the Repeated Distractor condition. Alternatively, the inhibition hypothesis predicts that repeated inhibition of the word "RED" would result in this word becoming increasingly suppressed thus diminishing its effectiveness as a distractor by reducing its competitiveness with the concurrent target colour. Again, this would allow for faster response in the Repeated Distractor condition.

Tipper et al. (1989) suggest that individual differences in an experiment designed to test for both NP and repeated distractor effects may allow for differentiation between the two competing hypotheses concerning repeated distractor facilitation. Because Tipper and his colleagues predicted that children should produce less evidence for negative priming than adults, a number of hypotheses concerning explanations of repeated distractor effects could be formulated. First, because the inhibition hypothesis predicts that repeated distractor and NP effects share the same underlying mechanism, as one effect declines (i.e., NP in children) the other effect should also decline. Therefore NP and repeated distractor effects should both be smaller in children than in adults on the basis of the defective inhibitory processing account. Second, and conversely, if the habituation hypothesis of repeated distractor effects is correct, a correlated decline in both NP and repeated distractor effects need not occur. Instead, a dissociation may be observed if each effect has a different underlying mechanism. That is, while negative



priming may be smaller in children than in adults, repeated distractor effects may not change, or may even be larger. If so, this would suggest that habituation mechanisms in children may be intact and at a level comparable to those in adults.

Stimuli employed in Tipper et al.'s (1989) experiment (hereafter referred to as the Stroop negative priming experiment) consisted of the words BLACK, BLUE, GREEN, RED, ORANGE, and YELLOW, or rows of printed X's, all of which were present in one of the six corresponding colours according to experimental condition. Four conditions were involved. In the Neutral Condition rows of X's, ranging from three to six X's per display, were presented in the different target colours. In the Repeated Distractor condition the distractor word in each item was the same throughout the list while target print colour changed. In the Stroop Control condition incongruent Stroop stimuli were used and there was no relationship between the stimuli from one trial to the next. In the IR condition the distractor colour word in the previous item was the same as the subsequent print colour target. Measures of interference (distractor intrusion; i.e., a Stroop effect) were calculated by comparing the Neutral condition with Stroop Control; habituation by comparing the Repeated Distractor conditions with the Stroop Control; and NP by contrasting the IR condition with the Stroop Control. Repeated distractor facilitation was indexed by the speeded responses to the Repeated Distractor condition in contrast with Stroop Control.

Tipper et al. reported differences in the findings between the children and adults. More specifically, the results showed high levels of distractor intrusion and little evidence of NP in children. On the other hand, lower levels of distractor intrusion and significant levels of NP were found in adults. In addition, inhibition and habituation as mechanisms of attention were found to be dissociated and to share different developmental patterns, because although repeated distractor facilitation was found for both groups, this was more pronounced for children. On the basis of these results, taken collectively, Tipper et al. concluded that repeated distractor facilitation " ... is *not* a

product of the inhibition of competing stimuli, rather ... the effect appears to be due to habituation of the orienting response" (p.363). They further concluded that under-utilisation of inhibitory mechanisms is likely to account for children's greater distractability in conditions where distractor stimuli vary as opposed to conditions in which distractor stimuli are repetitive. Importantly, under-utilisation or compromised inhibitory processing was also used to explain the absence of negative priming in the children.

However, within Tipper et al.'s (1989) study a second experiment was conducted. It was intended to determine whether the conclusion obtained from the Stroop task, suggesting little evidence of NP in children, would generalize to other selective attention tasks that used different stimuli. This experiment was designed only to investigate levels of interference and NP and, as such, excluded the Repeated Distractor condition from its context. The visual selective attention task they employed presented subjects with prime and probe displays of everyday objects. In each display two simple line drawings out of a possible six would appear, one on fixation to which the participant's attention was to be directed, and one on either the right or the left to be ignored. Participants were required to name the picture appearing at the fixation point. There were three experimental conditions: Control - where the pictures in prime and probe displays were unrelated; Neutral - where the prime display was similar to Control, but the ignored distractor picture in the probe display comprised meaningless lines unlikely to produce response competition; and IR - where the ignored distractor picture in the prime display became the target stimulus in the probe display. Levels of interference were measured by comparing the Neutral with the Control condition and NP effects were measured by comparing the Control and IR conditions.

No significant levels of NP or interference were observed in children. However, although not statistically significant, results from the Ignored Repetition condition suggested the presence of possible trends towards NP in children, unlike their previous

experiment employing the Stroop task. Furthermore, NP was observed in 70% of these children which was comparable to the 70% of the adult participants who, as a group, did show significant NP in this experiment. Thus Tipper et al. (1989) concluded that the evidence for compromised inhibition in children is equivocal.

Tipper et al.'s (1989) ambiguous findings relating to the prevalence of negative priming in children necessitates further investigation. They themselves emphasised that such preliminary results were no basis to assert that children did not have the ability to inhibit distractors. Instead, they suggested that the utilisation of inhibitory mechanisms in children may emerge under certain task conditions/situations, adding that investigation of the development of particular attention mechanisms, such as habituation and inhibition, may explain the appearance of these components and their role in determining performance in different task situations.

The only other study to examine conceptual NP in children was recently undertaken by Simone and McCormick (1999). These authors found significant NP effects using a location-based experimental design to investigate inhibition associated with concepts. Experimental designs used in NP studies can either be conceptually-based (non-spatial) or location-based (spatial). Conceptually-based tasks require participants to select target objects on the basis of a physical attribute such as colour or shape, and respond by identifying the target object on the basis of this feature either verbally or via a corresponding keypress. In these designs the critical target is typically positioned at a central location, or target and distractor are superimposed. NP effects are gauged on the basis of a non-spatial feature of the prime distractor that is either identical to, or semantically related to the probe target. Participants in location-based tasks also select an object on the basis of a physical attribute but respond to the location of the object. A visual display in a location-based task usually consists of four distinct locations, one of which contains a distractor stimulus and one of which contains a target stimulus. Participants are required to select the target stimulus and respond to its location either

manually or verbally. In this situation NP effects are measured on IR trials in which the probe target appears in the location previously occupied by the prime distractor and are thought to reflect that the location of the distracting information has been inhibited (see May, Kane, & Hasher, 1995 for a review). Simone and McCormick state that conceptual NP can be examined within a spatial design if participants are required to respond verbally or manually to a non-spatial feature of the target within a spatial array.

The motivation for Simone and McCormick's (1999) study was as follows. They noted that the study by Tipper et al. (1989), which used a conceptually-based, non-spatial experimental design, failed to find NP effects in children. On the other hand, the study by Tipper and McLaren (1990), which used a location-based experimental design to assess NP effects for children, found significant levels of negative priming for children as young as five. They also noted that stimuli in Tipper and McLaren's experiment consisted of a target "O" and a distractor "+" in which participants were required to respond to the location of the target "O". In the IR condition the location of the ignored "+" in the prime display was identical to that of the target "O" in the probe display. Locations of the target and distractor in the prime and probe displays were all different in the Control condition. NP effects were gauged by comparing response times in the IR condition relative to those in the Control condition. Tipper and McLaren's findings suggested to Simone and McCormick (1999), that because children demonstrate intact location NP effects it might be the case that only location-based tasks create conditions under which it can be demonstrated that young children also show conceptual NP effects. This, however, may be incorrect.

For example, Tipper and McLaren (1990) presumed the NP effect they observed in their study reflected inhibition associated with the spatial locus of the distracting object. According to Park and Kanwisher (1994), this account may not be correct. Rather, the NP effect observed by Tipper and McLaren is likely to have been caused by perceptual mismatching - an impairment caused by a mismatch of information between the prime

and probe. That is, as the ignored prime was a "+" and the subsequent probe an "O", and because the probe target appears in the same location as the ignored prime on IR trials, two identities become associated with the same location. A delay in response is incurred not because of inhibition, but rather because the position formerly occupied by the "+" must be revised and updated to reflect the fact that the "O" now occupies that position. This mismatch and the extra time to resolve it does not happen in Control trials. This non-inhibitory account of IR NP effects in this type of spatial task was derived from the "object file review" theory (Kahneman, Treisman, & Gibbs, 1992) described in more detail below.

In reviewing the "object file review" theory, Milliken, Tipper, and Weaver (1994), acknowledged that the delay in response time on IR trials in spatial tasks may reflect a cost associated with the recognition of a second identity at a single location rather than the consequence of distractor inhibition. In a spatial task, a current perceptual event that corresponds in location to a past perceptual event evokes an automatic retrieval of an object file associated with the past event. From this perspective, delayed response on IR trials in location-based tasks is not due to inhibition, rather it occurs because the various properties retrieved from the existing object file do not match those of the current perceptual event. In light of this, it is not clear why Simone and McCormick (1999) included Tipper and McLaren's (1990) experiment in the motivation for their study. As described above, it is highly unlikely that children in Tipper and McLaren's experiment demonstrated NP effects on the basis of distractor inhibition. Rather, as in other spatial localization tasks of the particular kind they used, IR impairment in responding was due to object file review mismatch delay. Nevertheless, Simone and McCormick went on to suggest that inhibition associated with location in a spatial task appears to emerge early in development as opposed to conceptual inhibition in a non-spatial task which appears to be developmentally mediated. It was also implied by these authors that localization may thus play a pivotal role for the appearance of conceptual NP effects in children.

Simone and McCormick (1999) proposed that a conceptual NP effect in children was more likely to emerge within the context of a spatial task with location as a salient feature rather than in the context of a non-spatial, semantic or identity based experimental designs such as the ones used by Tipper et al. (1989). Note, however, that NP effects in spatial localization tasks are notoriously controversial. NP effects in these designs are not always attributable to distractor inhibition as discussed in the preceding paragraphs (see Milliken et al., 1994, and Park & Kanwisher, 1994).

To investigate conceptual NP effects in children (6 - 8 years) Simone and McCormick (1999) employed the following spatial experimental design. A touch-sensitive colour monitor was used to present visual stimuli and record response times and error rates. Stimuli consisted of plus sign, square, star, and triangle. There were four stimulus locations in a display, each underlined with a black line regardless of whether or not a stimulus appeared in the location or not. The selection cue for the target in each trial was denoted by a central stimulus shape. Apart from the central stimulus only the two stimuli representing target and distractor appeared in any one display. The presentation of target, distractor, and search cue in any one display was simultaneous. Participants were required to respond by touching the target on the screen that matched the central stimulus shape. In each display the target stimulus appeared in one of the four locations along with a distractor stimulus (different shape) which appeared in one of the remaining three locations.

Experimental conditions of interest comprised three types of IR conditions respectively labelled "L", "I", and "LI". In all of these conditions the selection cue for the target was shape. Condition "L" assessed NP effects for location only. Therefore the probe target shared the same location as the prime distractor but not the same identity. Condition "I" assessed NP effects for identity only. Accordingly, the probe target shared the same shape type as the prime distractor but not the same location. Condition "LI" was designed to assess NP effect for both location and identity. Thus, the probe target

shared the same location and identity as the prime distractor. A control condition in which the probe distractor and target shared neither location nor identity with the prime distractor or target, was used to calculate measures of NP.

NP was obtained for all conditions. Simone and McCormick suggested that findings relating to condition "I" demonstrated inhibition directed toward stimulus shape, condition "L" demonstrated inhibition directed toward the spatial locus of a distractor, while condition "LI" demonstrated that inhibition in children can be guided by both location and conceptual properties. The conclusion given by these authors was that conceptual NP effects in children appear to be intact. According to them, a spatial task allowed for the demonstration of conceptual NP effects in children; an effect that was not observed in Tipper et al.'s (1989) non-spatial task. Going further, Simone and McCormick suggested that conclusions such as those reached by Tipper et al., who failed to find conceptual NP in children and who assumed deficits in inhibition to be related to selective attention problems and cognitive failure, should be re-examined.

One of the main ideas to come out of Simone and McCormick's research is that conceptual NP effects may only occur in children in tasks where localization is a salient feature. Is it really necessary to use a spatial or localization-based experimental design in order to observe conceptual NP effects in young children? This question was addressed in each of the three experiments in the current study.

To summarize, developmental research with interference-sensitive tasks has found children to be inefficient selectors when compared with adults (see Lane & Pearson, 1982; Dempster, 1995). Tipper et al. (1989) suggest children's susceptibility to distraction may be accounted for by compromised distractor inhibition. According to Tipper et al. (1989), effective visual selection involves an inhibitory mechanism acting to suppress competing information derived from analysis of irrelevant stimuli. Conceptual NP effects may reflect the engagement of this inhibitory mechanism. No significant

conceptual NP effects were found with children in the context of Tipper et al.'s (1989) non-spatial tasks. However, the study by Simone and McCormick (1999) using a spatial localization task which had a conceptually-based component, found intact conceptual NP effects in children. The respective findings by Tipper et al. (1989) and Simone and McCormick (1999) imply that NP effects in young children only emerge in tasks that have an inherent spatial or localization component. As asserted below, however, this assumption may be incorrect.

As far as I am aware, since the appearance of Tipper et al.'s (1989) and Simone and McCormick's (1999) contradictory studies, no further research has been undertaken in order to resolve these equivocal positions on NP in children. The present study was designed to address the discrepancy in the conceptually-based NP literature with children. One of the main goals of the present experiments was thus to examine conceptual NP in children in tasks that do not involve any spatial or localization component. In particular, it addresses the development of the ability to inhibit irrelevant stimuli at varying age ranges by attempting to determine if the magnitude of conceptual NP varies as a function of age. Indeed, if NP were to emerge at all ages tested, it would strongly imply intact inhibitory mechanisms in children, even in non-spatial tasks.



## **2.0 EXPERIMENTS 1 AND 2**

Experiment 1 was devised to investigate conceptual negative priming (NP) effects in children using a variant of the Stroop negative priming task employed by Tipper et al. (1989). This study included a broader age range of participants starting with children as young as five years old. Because it was not known beforehand if the youngest children could read, Experiment 1 was designed as a variant of the Stroop negative priming task by employing stimuli that comprised flanking incongruent coloured blobs rather than incongruent colour words. As the logic for attributing NP to an inhibitory process suggests inhibitory mechanisms are deployed in situations where irrelevant stimuli compete with relevant stimuli for the control of action, use of a Stroop task involving words with children potentially below reading age would undoubtedly have removed any opportunity to detect NP in these children. Experiment 2 used Stroop stimuli more similar to Tipper et al.'s (1989) in order to re-assess whether young children would produce NP in this type of Stroop negative priming task if minor methodological changes are implemented. It also enabled a further test of the potential generalizability of the NP phenomenon for children as well as allowing me to determine if there is a developmental trend for older children to be more likely to produce NP than younger children when words are used as the distractor stimuli.

## ***2.1 Conceptual NP in Children Using a Non-Spatial Task: Theoretical and Contextual Considerations***

### ***2.1.1 Inhibition as a Source of Negative Priming***

In order to place the present research in its appropriate context, this section reviews the proposal that NP reflects inhibition operating during selection to reduce concurrent interference from irrelevant items. This proposition stems from activation-suppression models of attention that emphasize the operation of a dual mechanism during selection (e.g., Keele & Neill, 1978; Neill, 1977; Neill & Westberry, 1987; Tipper, 1985).

According to these models selection is postcategorical; initial analysis of both attended and unattended stimuli take place in parallel prior to selection. Subsequently, and because of this, the activated internal representations of target and distractor both compete for the control of action during selection. For response to be directed towards the target, selective processing operates as a dual mechanism with the internal representations of attended and unattended stimuli receiving further but differing analysis. More specifically, an excitatory mechanism functions to enhance the target representation while an inhibitory mechanism acts to suppress the competing distractor representation. Delayed response to a target previously processed as a distractor suggests that the internal representation of an ignored stimulus becomes associated with inhibition during the selection of a target stimulus in a prime display.

On a slightly different tack, Tipper and Cranston (1985) emphasize that it is not the perceptual representation of the stimulus itself that is inhibited, rather the inhibition is levelled at further processing linking perception with response. These authors suggest that inhibition mechanisms are required to de-couple or block the activation levels of the distractor's internal mental representations from overt response mechanisms. This delays their future reactivation, producing a NP effect. Inhibition associated with response blocking operates in a forward manner impairing response to subsequent attended representations of the distractor stimulus.

Furthermore, the extent of inhibition associated with response output appears to be determined by processing demand (degree of difficulty involved in target selection) in the probe trial in both Control and IR conditions, according to Tipper and Cranston (1985). In a series of studies investigating the generality of inhibition across different types of IR trials, Tipper and Cranston found the level of inhibition for unattended stimuli in the prime trial to be influenced by the nature of the display in the subsequent probe trial. When the probe display in a series of Control and IR trials did not require selection processes, because there was no distractor present, a facilitatory effect was observed for response to IR trials relative to Control instead of the usual impairment. A NP effect for IR trials only occurred when selection was required due to the presence of a distractor in both prime and probe trials. On the basis of this pattern of results they concluded that inhibition is part of a strategic set called a "selection state" engaged to cope with the selection requirements across the prime and probe trials of NP experiments. According to this notion, if selection is not upheld across probe trials, the inhibition associated with response output for the distractor stimulus on the prime trial quickly dissipates, while the activation associated with its mental representation persists and facilitates response output to its re-presentation on the probe trial in the IR condition.

From this perspective, it would appear that if the difficulty of target selection is increased, a larger level of inhibition acting on distractor stimuli is likely to be required. This would, in turn, tend to produce larger NP effects. The reverse scenario holds for any reduction in selection difficulty. Thus, continued maintenance of the "selection state", due to continuous anticipation of conflicting stimuli across trials, appears to be an important factor in the manifestation of NP.

Could the lack of NP effects for children in Tipper et al.'s (1989) study relate in some way to a reduction in the strength of the "selection state" caused by Tipper et al.'s inclusion of the repeated distractor condition and/or the neutral condition within the

context of trials testing for NP? For the reasons outlined above, repeated distractor or neutral conditions, where processing demand is likely to be minimal, may have lessened "selectional concentration" to a degree that was detrimental for the appearance of NP effects in children. The following review of NP research using nonconflict stimuli (i.e., probe trials which do not include a distractor to conflict with the correct response) provides some additional empirical support in favour of this idea. Because it turns out to have an important bearing on the interpretation of the present experiments, in relation to those reported by Tipper et al. (1989), it is necessary to go into a fair amount of detail here.

The general indication from studies using nonconflict stimuli has been that reductions or even reversals in NP are observable when selection is not required in probe trials. The same holds true when the majority of probe trials have not involved selection, or when expectations of processing difficulty are low (see May, Kane & Hasher, 1995, for a review). The inhibition hypothesis of NP would suggest that these contextual variables may "...induce participants to abandon 'selection states' when responding, resulting in a rapid dissipation of inhibition and consequently a reduction or reversal of negative priming" (May, Kane & Hasher, 1995, p.45). Inducing a heightened "selection state" may therefore be an important determinant of NP.

Studies by Moore (1994) have offered a more precise account of the conditions under which failures to observe NP occur - especially with regard to processing demand in IR probe trials. As did Tipper and Cranston (1985), Moore (1994) found that NP failed to occur when Control and IR probe trials were nonconflict relative to conflict Control and IR probe trials (i.e., contained a distractor that would conflict with the correct response). According to Moore, the failure of inhibition to manifest itself was determined by "ease" of identification of probe trials as nonconflict. That is, NP would fail to occur on nonconflict IR probe trials only when Control and IR conditions were easily identifiable as including no information that could conflict with the correct response.

Ease of identification was moderated by two factors within the experimental context: the similarity between conflict and nonconflict Control and IR probe trials; and the predictability of whether or not an upcoming probe trial would be nonconflict.

Similarity and predictability were manipulated in two ways. First, nonconflict Control and IR trials could either have no distractor, or contain a distractor but one that was not from the same set of stimuli used for the target and therefore would not compete for response selection. Second, series of conflict and nonconflict trials were presented either independently (pure blocks) or intermixed (mixed blocks). Importantly, NP failed to occur only when probes were predictably nonconflict trials (i.e., in pure blocks) or when nonconflict trials could be easily discriminated from conflict trials (i.e., nonconflict probe trials not containing distractors as opposed to nonconflict probe trials containing distractors) in mixed blocks. NP effects were, however, observed on both conflict and nonconflict probe trials when mixed blocks were used.

According to Moore (1994), the results of these experiments implied that while NP effects reflect inhibition maintained as part of the selection process, the specific purpose of this inhibition is to prevent the system from response elicitation based on incorrect information. As such, it may function as a "protective process" which can be engaged conservatively according to experimental context. NP only occurred during conditions where it was possible for incorrect information to elicit a response; i.e., when both target and distractor are associated with viable responses (conflict probe trials) or when it was impossible to predict whether or not a non-conflict probe was about to appear (nonconflict probe trials in mixed blocks). NP fails to occur when "protection" is not necessary (nonconflict probe trials in pure blocks).

In summary, it would appear that NP effects are largely governed by a "selection state" designed to protect the response system from erroneous information when processing demand is high during selection. However, under special circumstances this protective

process can be utilized even when processing demand is reduced but expectation of selection remains high. In short, "selection state" can vary in intensity from low to higher degrees. Moreover, the degree of intensity to which the "selection state" is set is determined by both processing demand and expectations about processing demand induced by experiment-wide contextual factors.

Research by Khurana (2000), investigating NP effects for unfamiliar human faces represented in photographic stills, has also emphasized the importance of response conflict in both prime and probe trials. Khurana (2000, Experiment 1) found an increase in reaction time when a target in the probe trial had appeared as a distractor in the preceding prime trial. This indicated that unfamiliar faces are represented and require inhibition. However, further experiments manipulating information available for distractor faces in Control and IR trials found that the level of inhibition depended on strength of response competition inherent between target and distractor in prime and probe trials. For instance, a decrease, rather than an increase, in reaction time was observed for IR trials when the photographic still of the face target in the probe display had previously appeared in a degraded form (i.e., either corrupted with high-frequency noise or contrast inverted) as the distractor in the prime trial.

According to Khurana (2000) these results suggested that inhibition "...is a function of the nature of the internal representation of the distractors, in so far as the distractor representations vie for response selection and the control of attention in a given task" (p.252). Facilitatory effects for IR trials using degraded distractors implied that degraded distractors were activated in initial analysis on the prime trial and represented as internal mental images. This activation then remained or persisted to facilitate response to the distractors re-presentation as a target on the probe trial. The persistence of this activation suggested that although degraded distractors were represented they did not offer strong competition to targets in the process of selection and directed action, hence the lack of inhibition and NP effects. These results were taken to infer that

inhibition exists as a flexible entity largely dependent on the strength of selection difficulty in Control and IR trials.

### ***2.1.2 Maximizing Attentional Selectivity.***

Inhibition as a potential source of NP is apparently reactive to situational factors within the experimental context. Specific determinants appear to be: 1) degree of selection difficulty in the probe trial and the maintenance of this across Control and IR trials; 2) identification and/or anticipation of selection difficulty in probe displays across Control and IR trials; and 3) the similarity between distractor and target representations in both prime and probe trials across IR trials.

Clearly, NP effects are more likely to emerge within experimental contexts which facilitate and maintain selection difficulty across both prime and probe trials. This implies that engagement of a protective "selection state" is sensitive to "selectional concentration", maximally operational when expectation of processing demand and/or degree of competitiveness between target and distractor is high.

The current study comprises three experiments conducted to investigate the occurrence of conceptual NP in children between the ages of five and 12 using conceptually-based, non-spatial designs. A diverse range of stimuli and procedures was employed. Obtaining significant NP in this study would: a) directly contradict findings by Tipper et al. (1989); b) corroborate Simone and McCormick (1999) findings regarding NP levels in children, while extending their findings to include conceptual NP in a non-spatial task; c) provide evidence for the possible existence of inhibitory mechanisms of selective attention in children; d) provide evidence for possible developmental influences on NP levels; and thus e) have important theoretical implications concerning the development of an inhibitory selective attention mechanism during childhood.

Whilst Tipper et al. (1989) investigated NP in children using experiments which were also designed to simultaneously test for distractor interference and habituation by

comparing Neutral and Repeated Distractor trials with Stroop Control trials, the current experiments will only employ the experimental conditions which test for NP (i.e., Control and IR trials). Importantly, the presence of the Neutral and Repeated Ignored conditions, designed to test for distractor interference and habituation, within the context of trials testing for NP, may have had unfavourable repercussions for obtaining NP effects in children. The reasoning behind this proposition concerns the influence of experiment-wide selection requirements on the engagement of "selection state".

More specifically, processing demand within the Neutral and Repeated Distractor conditions may be quite minimal. Although target selection is required, there is little competitiveness between target and distractor levelled at response selection because the same distractor was repeatedly re-presented in these conditions. Consequently, as there is likely to be lessened expectation or anticipation of processing difficulty across these trials, the intensity of "selection state" within the entire experimental context may be reduced. In my view, this may underlie the reported absence of Stroop NP in children by Tipper et al.(1989).

Preliminary support for this contention comes from the second of Tipper et al.'s (1989) experiments concerning NP in children. Although there was no evidence whatsoever for NP in their Experiment 1, there was a slight trend (albeit non significant) for NP in their second experiment. This relative increase in NP levels may relate to the removal of the Repeated Distractor condition (used in their Experiment 1) from the context of their second experiment. Recall that the design of the Repeated Distractor condition demands that one distractor Stroop colour-word be repeated throughout its particular trials. This continuous repetition of one colour-word within the context of Tipper et al.'s first experiment may have eased selection. Thus, as there was less incentive for subjects to ignore these distractors across all conditions in this experimental situation, expectation of processing demand was not upheld. Consequently, distractor representations that cease to vie for response selection lessen the degree of vigilance or



"selection state" resulting in the dissipation of the inhibitory process and the abatement of NP effects.<sup>1</sup> It is also possible that the inclusion of the Neutral condition (the effect of which is likely to be similar to that of the Repeated Distractor condition) in Experiment 1 further exacerbated the potential for a reduced "selection state."<sup>2</sup>

Exclusion of the Repeated Distractor condition from the context of Tipper et al.'s (1989) second experiment may have encouraged the utilisation of a more concentrated "selection state" hence the observable trends towards NP. It is my contention that significant levels of NP would have been obtained from this experiment had (1) the Neutral condition also been removed from the context, and (2) spatial separation of the target and distractor been reduced. A number of studies have revealed that close target-distractor separation, as opposed to distant target-distractor separation, increases the difficulty of target selection (e.g., Fox, 1995). It may be that inhibitory mechanisms in

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<sup>1</sup> Because no positive priming effects were obtained in the ignored repetition condition of this experiment, it is possible that inhibitory mechanisms underlying NP were engaged sufficiently to outweigh any facilitatory effects of persisting distractor activation. This would suggest that the "selection state", although greatly minimised, was not abandoned.

<sup>2</sup> Effects similar to this have, in fact, been noted in current NP studies on adults by Neumann (2000) employing Stroop NP experiments. When one-third of the trials within the context of a Stroop NP experiment contained congruent Stroop stimuli (a condition whereby colour words matched the hue of the colour box in which they were present) there was a significant trend towards positive priming in the ignored repetition condition, relative to a control condition. Neumann suggested that the presence of congruent Stroop stimuli within the context of Stroop NP experiments may provide less of an incentive for participants to ignore the irrelevant word, because this information has been helpful on past trials where hue and colour-word match. If this leads to a generalised reduction in the "selection state" across conditions this may account for the reversal of negative to positive priming in this particular experiment.

children are also sensitive to variations in selection requirements affecting their "selection state" as are adults. Stronger levels of inhibition may be required in children to suppress distractor activation when distractors are consistently highly competitive with targets.

## **2.2 Experiment 1 - The Colour Blob Task**

The original development of this task was motivated by concern about the suitability of the Stroop task for use in a negative priming paradigm with children potentially below reading age. Given the importance of distractor interference in the initiation of inhibitory mechanisms and hence NP effects, the use of a Stroop paradigm with children as young as five years seemed inappropriate. It was not known in advance whether the reading skills of children below the age of seven included in the current study would be sufficiently advanced so as to produce automatic processing of the irrelevant distractor words typically used in a Stroop task.

Because heightened Stroop interference coincides with the onset of word reading ability at around age seven (see Comalli et al., 1962), it was deemed questionable whether significant NP effects would be obtainable for children aged 5 - 6 years using a Stroop paradigm with words. Because it was questionable whether word reading had become fully automatized (if at all) at this early age, word reading might be subordinate to colour naming in this age group. And, as discussed earlier, inhibitory mechanisms would not be implemented in situations where distractors do not interfere or compete with target selection. However, this is not to say that inhibitory mechanisms of attention do not exist in children of this age group. Rather, it is proposed that the engagement of inhibitory mechanisms would be more likely to occur in situations where representation of relevant and irrelevant stimuli at least initially receive equivalent amounts of activation

and are thus competitive with one another. Presumably even the youngest children would be familiar with the names of the ink colours used in the present task.

Because colour-processing, and hence colour-naming, may dominate over form-processing in children who have not yet learned to recognise letter forms (Arochova, 1971, reviewed in MacLeod, 1991), it seems reasonable to assume that situations in which relevant and irrelevant stimuli comprising incongruent colours could potentially evoke high levels of interference in young children as conflicting colour representations may each become activated. In such situations it is possible that target selection will be complemented by an inhibitory mechanism acting to block competing distractor information. As such, any IR trials which employ incongruent colour stimuli, in my view, should produce significant NP effects in children aged even as young as 5 and 6 years.

The following experiment investigated the two-fold hypothesis that the exclusion of Repeated Distractor and Neutral conditions from within the context of NP trials will intensify children's engagement and maintenance of a "selection state" and that this in turn will allow for the observation of significant NP effects. Unlike Tipper et al.'s (1989) Stroop negative priming paradigm with children aged 7 - 8 years, this experiment employed a flanker-like task with a more extensive range of colour stimuli. A more developmentally informative age range was also used. Whether children aged 5 - 6 years would show significant NP for incongruent colour stimuli in IR trials and whether these effects would be obtained and remain constant in children of older age groups (8 - 9 years and 11 - 12 years) is of considerable empirical and theoretical interest. Additionally, if significant NP effects were to be obtained with the experimental task outlined below, this task could serve as an empirical tool allowing further investigation into the development of inhibitory mechanisms in children below reading age.

These possibilities were examined through a newly-devised task in which target and flanking distractor colour blobs were presented in incongruent colours. Each display consisted of three colour blobs, the central one functioning as the target and the flanking (outer) blobs as the distractors to be ignored. The time taken by participants to name the colour of central blobs was recorded by stopwatch. Original work using flanker paradigms by Eriksen and Eriksen (1974; reviewed in Brown & Fera, 1994) has shown that when flankers are incompatible with the target response, response time (RT) is slowed. In order to maximise selection difficulty in the colour-blob experiment, blobs were presented in close proximity to each other, with intermeshed contours. Much research with flankers has demonstrated RT increases with reduced spatial separation of flankers from the target (Brown & Fera, 1994).

It is predicted that collectively, the above experimental manipulations will induce a heightened "selection state" which in turn should boost NP effects in children to a significant level. In addition it was hoped that the inclusion of a NP task more developmentally suited to young children would allow for the observation of NP effects in the youngest age group. Strong support for these hypotheses would be evidenced if significant negative priming was observed in all three age groups.

### **2.2.1 Method**

#### ***Participants***

One hundred and fifty children (60 males and 90 females) attending years 2 - 8 in four primary schools and one intermediate school in the Christchurch area participated in this experiment. Following approval by the University of Canterbury Human Ethics Committee, children were selected from schools that agreed to take part in the study and were recruited on a volunteer basis with parents giving written consent for their child's participation (Appendix A). All participants had normal colour vision and normal or corrected-to-normal visual acuity. Participants were grouped by age to include fifty 5 -

6 year-olds, fifty 8 - 9 year-olds, and fifty 11 - 12 year-olds. The average age for the youngest group was 6 years and 3 months (range 5 years 2 months to 7 years 1 month). The average age for the middle group was 8 years 8 months ( range 8 years 0 months to 10 years 0 months). The average age for the oldest group was 11 years and 9 months (range 10 years 10 months to 13 years 0 months).

### ***Design***

A mixed design was employed. The between-subjects variable was age group (5 - 6 yr olds versus 8 - 9 yr olds versus 11 - 12 yr olds). The within-subjects variable was priming condition (Control versus Ignored Repetition). Half the trials in the experiment proper were Control trials (where the colour of the prime distractors and the target probe were unrelated) and half Ignored Repetition trials (where the colour of the distractors in the previous display were the same as the subsequent target colour). The distribution of stimuli across participants and conditions in the experiment was counterbalanced.

### ***Apparatus and Stimuli***

Stimuli were presented on 32- x 22-cm manilla cards, each card comprising 11 sets of three different shaped colour blobs. A single colour blob shape in a set measured 2.0 cm in height and approximately 3.0 cm in width. The sets of three blobs were presented as rows arranged at 1.5 cm intervals apart in a vertical column per card. All rows were unique with no one blob shape appearing more than once on a card. On any given card rows of blobs were randomly arranged to appear slightly to the left or right. Shifting the rows in this way was intended to help reduce the saliency of the IR condition. Examples of Control and IR colour blob cards are presented in Appendices B and C. Visual distances between the target blobs and individual blob rows were the same for both IR and Control cards. The centre blob on each row functioned as the target and outer blobs functioned as distractors. The flanking distractor blobs were always presented in an identical colour which differed from the target colour. Colours

for blobs were: purple, blue, red, yellow, brown, pink, orange, green, white, black, and gray. These stimuli were presented in accordance with the two experimental conditions which consisted of six cards each. However, to further counter the potential saliency of the Ignored Repetition condition, target colours in the first prime-probe couplet on each IR card were unrelated. There were four additional colour blob Control cards that were used for practice trials.

Stimulus representation was counterbalanced. Each of the 11 rows of blob shapes appeared only once on each card. On a given card, each colour appeared twice, once as a distractor and once as a target with the following exception. This did not hold for IR cards as the inclusion of one unrelated prime-probe couplet at the very beginning meant that one blob colour had to appear twice as a target to the exclusion of another. This meant that while each Control card had 11 different target colours to be named, an IR card would only have 10 different target colours to be named. However, the total number of target colours to be named was the same for both the Control and IR cards. Although IR cards only had 10 different target colours to be named one of these would re-appear to be named for a second time. (Appendix E contains a supplementary control experiment using only Stroop Control cards in order to determine whether any detrimental artifact could have evolved from presenting a duplicate colour in the IR condition. Two conditions were assessed. Naming 11 unique colours once versus naming nine unique colours and one duplicate colour twice. The results from that experiment ruled out the possibility that including one duplicated target colour could yield a delay compared to cards with no duplicated target colours. Thus the interpretation of IR NP effects in the present experiment would not be compromised by this potential artifact). Presentation orders in the experiment proper were counterbalanced so that half of the participants began with a Control card and the remaining half began with an IR card. Subsequent cards were presented in regular alternation of the two conditions. A stopwatch was used to measure all response latencies up to the completion of colour naming for each card.

### ***Procedure***

Participants were tested individually in a quiet room in one session lasting approximately 15 minutes. At the beginning of each session participants completed a preliminary colour vision task in which they were presented with the colours used in the experiment on a card. This card consisted of eleven squares printed in the colours purple, blue, red, yellow, brown, pink, orange, green, white, black, and gray. The participants were instructed to name each colour as a test for both colour vision impairment and familiarity with colour names. No participants had any difficulty with this task.

Participants were then verbally instructed to name as quickly and accurately as possible the colour of each centre blob while ignoring the outer blobs, from the top to the bottom of the column on the card. These instructions are presented in Appendix D. Participants were informed not to stop if an error was made but to continue until the colour naming for the card was completed. Each participant encountered four Control practice cards before the commencement of test cards. Participants, however, were only informed that the first three cards were practice trials. As far as the participants were concerned, the last practice card was treated as the first experimental card. There were two reasons for this. First, it was hoped that this manipulation would help prevent any of the participants from noticing the systematic relationship between prime distractors and probe targets on IR trials. Studies by Hasher, Quig, Stoltzfus and Goldstein (1995) and Stoltzfus, Hasher, Zacks, Ulivi and Goldstein (1993), reviewed in May et al. (1995), have shown that participants who are aware of the NP manipulation can sometimes, under circumstances in which the knowledge is useable, use this information to predict test targets. This may result in reduced NP or even a reversal toward positive priming. Second, research by Neumann (2000) found increased NP levels when numbers of IR trials within an experimental context were at 25% with 75% control trials, as opposed to 50% and 50%.

The practice cards were then followed by 12 test cards (six per condition presented in alternation). For each card the experimenter said "Ready" as a warning, and on the word "Go" a blank card covering the test card was removed and the stopwatch started. The stopwatch was stopped when the participant had named the last target colour blob in the column displayed on the card. Error scores for each card were also noted.

### 2.2.2 Results

For each participant a mean response time (RT) was computed from the six cards representing the Control condition and the six cards representing the IR condition. Mean (RTs) and percentage of errors for the Control and IR conditions are shown for the three age groups in Table 2.2.1.

*Table 2.2.1 Mean Reaction Times (in Milliseconds) and Percentage of Errors for each Age Group as a Function of Priming Condition in Experiment 1*

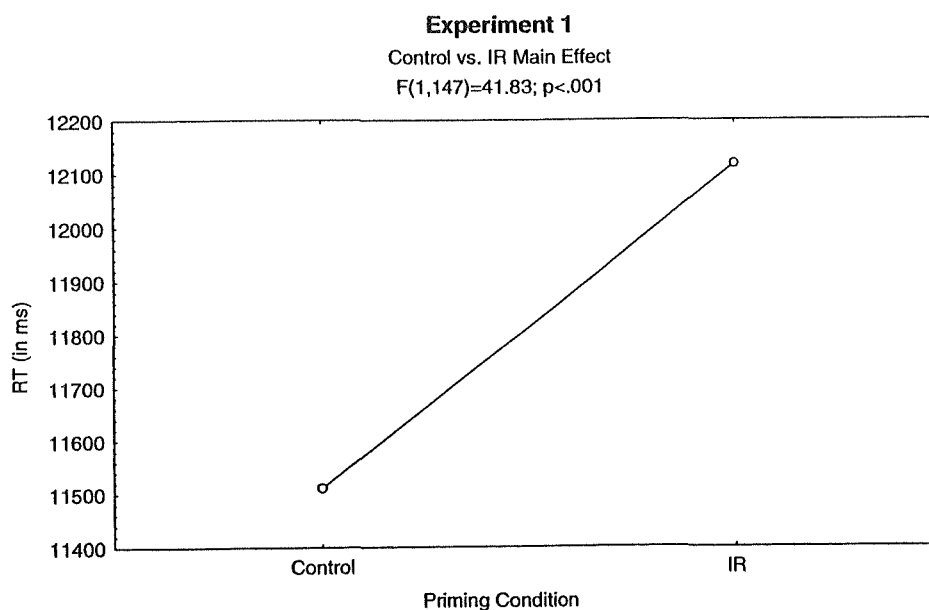
	5 - 6 yr olds	8 - 9 yr olds	11 - 12 yr olds
Condition			
<u>Control</u>			
M	15530	10593	8411
SD	4671	2470	1840
ER (%)	1.6	1.1	1.2
<u>IR</u>			
M	16370	11076	8908
SD	4431	2378	1820
ER (%)	2.5	1.4	2.0

#### *Reaction Time Analysis*

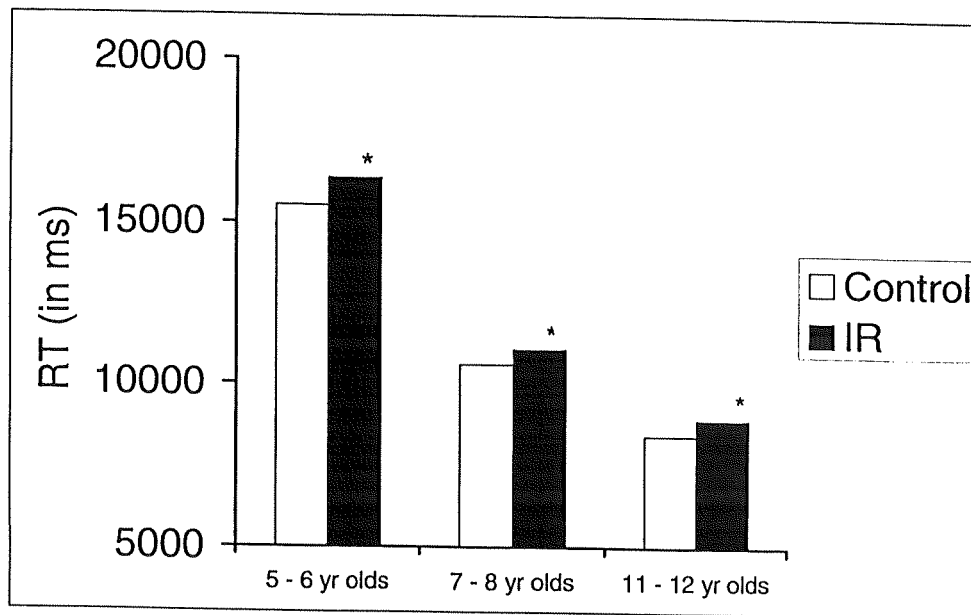
A two-way mixed design analysis of variance (ANOVA) was carried out on the mean RTs. The between-subjects factor was age group (5 - 6 yr olds versus 8 - 9 yr olds versus 11 - 12 yr olds) and the within-subjects factor was priming condition (Control versus Ignored Repetition). The between-subjects factor of age group was significant,



$F(2,147) = 72.56; p < .001$ . In order to determine whether there were differences in the overall RTs between the different age groups, Newman-Keuls post hoc analyses were conducted. The results indicated that the 5 - 6 yr olds responded significantly more slowly than the 8 - 9 yr olds and the 11 - 12 yr olds, and the 8 - 9 yr olds responded significantly more slowly than the 11 - 12 yr olds (all  $p$ 's  $< .01$ ). The finding of longer response latencies with younger children is not uncommon (see Kail, 1988; and Bisanz, Danner, & Resnick, 1979). More critically, the within-subjects factor of priming condition (Control versus Ignored Repetition) was significant,  $F(1,147) = 41.83; p < .001$ . Participants responded slower on the IR trials than on Control trials (see Figure 2.2.1.). Finally, the interaction between priming condition and age group did not approach statistical significance,  $F(2,147) = 1.55; p > .21$ . The NP effect thus appears similar across the age groups and was unrelated to overall processing speed (see Figure 2.2.2). The percentage of participants showing NP effects for each age group is shown in Table 2.2.2.



**Figure 2.2.1. Experiment 1: IR versus Control main effect.**



*Figure 2.2.2. Experiment 1: NP effect as a function of age group*  
*\*  $p < .001$*

*Table 2.2.2 Percentage of Participants showing NP Effects in Experiment 1*

Age group	% of NP Effects
5 - 6 yr olds	80%
8 - 9 yr olds	72%
11 - 12 yr olds	82%

### **Error analysis**

Similar analyses were conducted for error scores. The between-subjects factor of age group (5 - 6 yr olds versus 8 - 9 yr olds versus 11 - 12 yr olds) was marginally significant,  $F(2,147) = 2.76$ ;  $p < .07$ . The within-subjects factor of priming condition (Control versus IR) was significant,  $F(1,147) = 14.94$ ;  $p < .001$ . Participants made more errors on IR trials than on Control trials. Finally, there was no significant interaction between priming condition and age group,  $F(2,147) = 1.44$ ;  $p > .24$ . Thus,

the error results clearly corroborated the RT results; there was no indication of a speed-accuracy trade off.

## **2.3 Discussion**

The main objective of the current experiment was to resolve ambiguous findings with conceptual NP in children obtained from previous studies. The results reported here clearly demonstrate intact conceptual NP in children aged five and upwards. These findings contradict those reported by Tipper et al. (1989) and extend the results obtained by Simone and McCormick (1999) to include conceptual NP in a non-spatial task. The significant levels of NP effects obtained in Experiment 1 suggest children have an inherent ability to inhibit distractors at least from the age of five. Moreover, the magnitude of conceptual NP in the present non-spatial task did not vary as a function of age.

### ***2.3.1 NP Effects in Children***

The present results provide preliminary support for an intact inhibitory mechanism of visual selective attention in children. Moreover, this inhibitory mechanism appears to be in place and operational by age five. Despite the plausibility of the assumption that children's susceptibility to distraction is attributable to deficient or weakened inhibitory functioning (Tipper et al., 1989), the significant levels of NP found in children from the age of five in Experiment 1 suggest otherwise. Development does not seem to moderate the existence or utilisation of inhibitory mechanisms in the age range tested in the present experiment. Although younger children might be more susceptible to distractor interference (as indicated by their larger overall RTs), the means by which this interference is overcome is apparently by the same inhibitory mechanism utilized by older children (as indicated by the similar magnitudes of NP produced by 8 - 9 yr olds and 11 - 12 yr olds).

Tipper et al. (1989) concluded from their findings that the means for inhibiting identity information is still immature by age seven. Simone and McCormick (1999), on the other hand, proposed that while NP associated with location appears to emerge early in development, conceptual NP in a non-spatial task may be developmentally mediated. The findings of the current experiment did not support the conclusions of either Tipper et al. (1989) or Simone and McCormick (1999). Rather, they serve to extend the results of Simone and McCormick (1999) to allow the inclusion of conceptual NP in a non-spatial design wherein the target was always located in the centre of the display - thus removing any spatial or localization aspect from the task. On the basis of the present results, it seems clear that the ability to inhibit conceptual information is in place by age five. They also support the hypothesis that experimental manipulations designed to intensify "selection state" by increasing and maintaining processing demand and expectations about processing demand across prime and probe displays in Control and IR trials may in turn boost NP effects in children to a significant level.

Having established significant NP effects for children between the ages of five and 12 with incongruent colour stimuli, a further issue concerns the generalizability of these findings across tasks. As mentioned earlier, NP effects have been demonstrated with adults across a wide range of stimuli and task demands. This suggests that NP, at least in adults, reflects the use of a common underlying inhibitory mechanism.

However, some caution is required before claiming either the generalizability or reliability of NP effects in children. It may be that levels of inhibition in children, relative to those in adults, are task and/or stimulus specific. Further investigation is needed in order to determine the generalizability of the NP phenomenon in children. To address this issue, a second experiment was designed using a modified version of Tipper et al.'s (1989) Stroop negative priming task.

## **2.4 Experiment 2 - Stroop Colour-Naming Task**

Experiment 2 used a modified version of Tipper et al.'s (1989) Stroop negative priming task in order to ascertain the generalizability of NP effects in children across experimental paradigms. Although the Stroop paradigm did not initially seem suited to assess NP effects for the youngest age group (5 - 6 yr olds), it was anticipated that any NP effects obtained for older children (8 - 9 yr olds and 11 - 12 yr olds) with this paradigm would provide further evidence for the existence of NP in children. Additionally, significant NP effects here, would further support the hypothesis concerning the influence of "selection state" strength on NP levels in children and thus would provide a strong empirical basis for future research regarding the development of NP. Furthermore, these results are likely to be of relevance to literature concerned with the developmental course of the Stroop effect.

As noted by Tipper et al. (1989), the Stroop task has properties which differ qualitatively from those in other more typical selective attention tasks. Unlike the colour blob task where selectivity was directed towards a single target object, participants in the Stroop task are required to respond to one of two conflicting dimensions of a compound stimulus. Significant NP effects in a Stroop NP paradigm for children for whom word processing has become automatized, would suggest that NP in children, as in adults, mirrors an efficient inhibitory mechanism capable of working on a range of stimuli types.

### **2.4.1 Method**

#### ***Participants***

The participants were from the same pool of individuals used in the previous experiment.

#### ***Design***

This experiment employed a variation of the Stroop negative priming colour-naming task used by Tipper et al. (1989). A more extensive range of Stroop colour stimuli were used. In terms of issues regarding the intensity of "selection state", the design of this experiment was similar to that of Experiment 1. Only Control and IR trials were used, the majority of these were Control trials. A mixed design was employed. The between-subjects factor was age group (5 - 6 yr olds versus 8 - 9 yr olds versus 11 - 12 yr olds). The within-subjects factor was priming condition (Control versus IR). Half the trials in the experiment proper were Control trials (where distractor colour words were printed in incongruent target colours, and no relationship existed between successive items in the list) and half Ignored Repetition trials (where throughout the list, the distractor colour word in the previous display named the subsequent target ink colour). The distribution of stimuli across participants and conditions in the experiment was counterbalanced.

#### ***Apparatus and Stimuli***

The stimuli were presented on 26- x 18-cm laminated cards and consisted of the words PURPLE, BLUE, RED, YELLOW, BROWN, PINK, ORANGE, GREEN, WHITE, BLACK, and GRAY. These were all printed as a vertical list and presented against a light gray background on each Control and IR card. Lettering measured 1.0 cm in height with each word spaced at 1.0 cm intervals down the list. The 11 Stroop items in each card were arranged in a single vertical column with the print of each word presented in one of the eleven corresponding colours. As with the colour-blob task, the

first prime-probe couplet on each IR card was unrelated in order to reduce the saliency of this condition. There were six Control cards and six IR cards within the experiment. Examples of Control and IR cards used in this experiment are presented in Appendices H and I. There were four additional Control cards that were used for practice trials. Each word and each ink colour appeared only once on a given card with an exception. This did not apply for IR cards. One ink colour had to appear twice as a target to the exclusion of another. The explanation for this is the same as has already been given in the method section of Experiment 1 (see also Appendix E). Presentation orders within the experiment were counterbalanced so that half the participants began with a Control card and the remaining half began with an IR card. Subsequent cards were presented in regular alternation of the two conditions. A stopwatch was used to measure all response latencies until the completion of colour naming for each card was completed.

### *Procedure*

Each participant was tested individually in a quiet room in one session with individual sessions occupying approximately 15 minutes. As with Experiment 1, participants first completed a preliminary colour vision task in which they were presented with the colours used in the experiment on a card. This card consisted of eleven squares printed in the colours purple, blue, red, yellow, brown, pink, orange, green, white, black, and gray. The instructions were to name each of these colours. Again, no participants reported any difficulty with this task.

Participants were then verbally instructed to name the ink colours of each word moving from the top to the bottom of the column on the card as quickly and as accurately as possible. These instructions are presented in Appendix J. Participants were again told not to stop if an error was made but to continue until the colour naming was completed. To give the participants practice in naming ink colours in the context of printed words, each participant encountered four Stroop Control practice cards before the commencement of test cards. Again, for the reasons outlined in Experiment 1,

participants were only informed that the first three cards were practice trials. The last practice card was treated as the first experimental card. Following these practice trials the participants were given the twelve test cards (six per condition presented in alternation). For each card the experimenter said "Ready" as warning, and on the command "Go" a blank card covering the test card was removed and the stopwatch started. The stopwatch was stopped when the participant had named the last colour in the list on the card. Error scores for each card were recorded.

## 2.4.2 Results

Mean RTs and percentage of errors for the Control and IR conditions are shown in Table 2.4.1. For each participant a mean RT was computed from the six cards representing the Control condition and the six cards representing the IR condition.

*Table 2.4.1. Mean Reaction Times (in Milliseconds) and Percentage of Errors for each Age Group as a function of Priming Condition in Experiment 2*

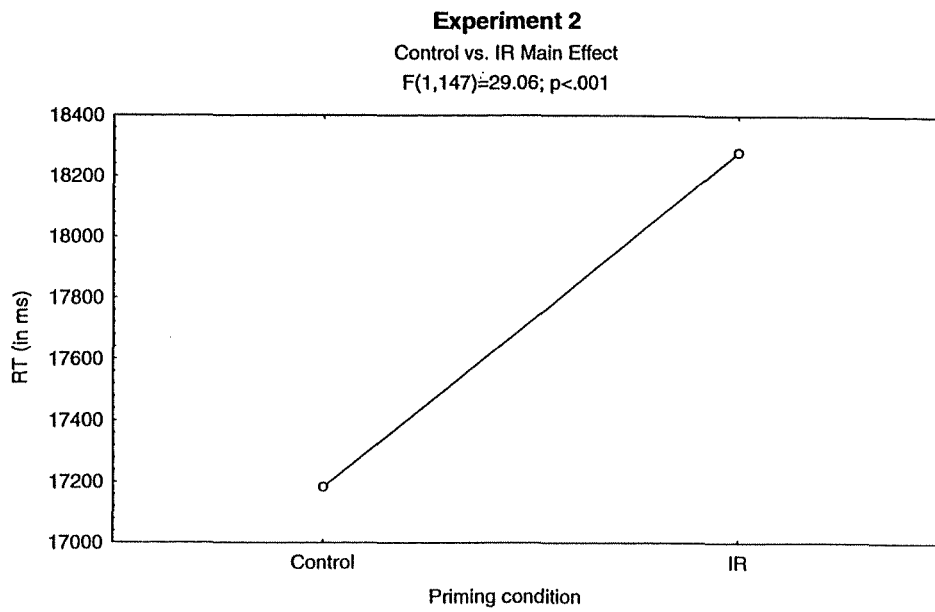
	5 - 6 yr olds	8 - 9 yr olds	11 - 12 yr olds
Condition			
<u>Control</u>			
M	23370	15881	12304
SD	6352	3668	2795
ER (%)	4.2	2.3	2.9
<u>IR</u>			
M	24955	16808	13079
SD	6781	4063	3072
ER (%)	5.2	2.8	3.8



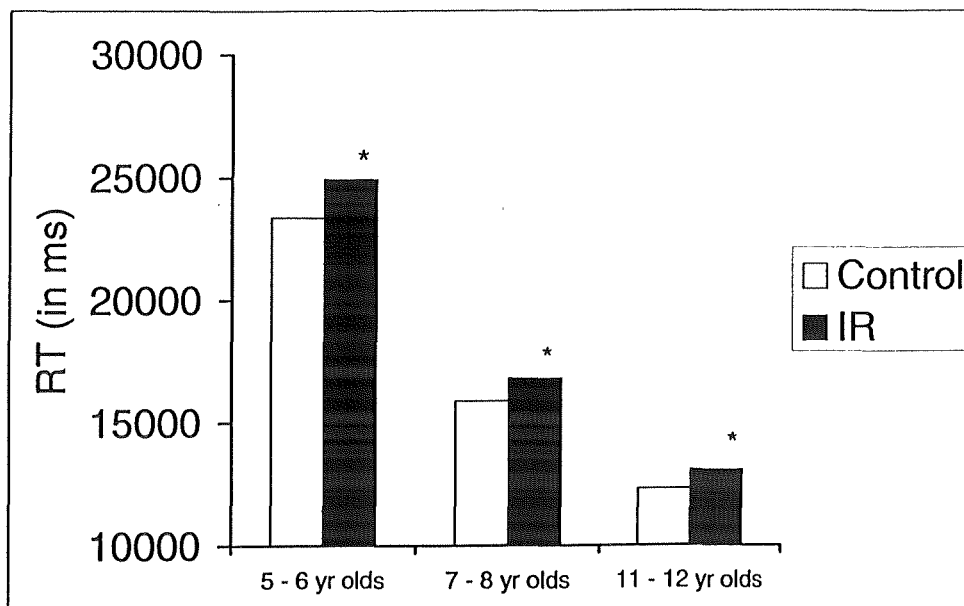
### ***Reaction Time Analysis***

A two-way ANOVA was carried out on the mean RTs. The between-subjects factor was age group (5 - 6 yr olds versus 8 - 9 yr olds versus 11 - 12 yrs old) and the within-subjects factor of priming condition (Control versus Ignored Repetition). The between-subjects factor was significant,  $F(2,147) = 82.92$ ;  $p < .001$ . In order to determine whether there were differences in the overall RTs between the different age groups, Newman-Keuls post hoc analyses were conducted. The results indicated that the 5 - 6 yr olds responded significantly more slowly than the 8 - 9 yr olds and the 11 - 12 yr olds, and the 8 - 9 yr olds responded significantly more slowly than the 11 - 12 yr olds (all  $p$ 's  $< .01$ ). More importantly, the within-subjects factor of priming condition (Control versus Ignored Repetition) was significant,  $F(1,147) = 29.06$ ;  $p < .001$ . Participants responded slower on the IR trials than on Control trials (see Figure 2.4.1.). The interaction between priming condition age group did not approach statistical significance,  $F(2,147) = 1.49$ ;  $p > .22$ . The NP effect thus appears similar across the age groups and was unrelated to overall processing speed (see Figure 2.4.2). The percentage of participants showing NP effects for each age group is presented in Table 2.4.2.

Although not anticipated, significant NP effects using the Stroop task were obtained even for the 5 - 6 yr olds,  $F(1,49) = 15.99$ ;  $p < .006$ . Upon later questioning, teachers reported that the reading skills of most of these children were sufficiently advanced to encompass knowledge of the colour words used in the present experiment.



*Figure 2.4.1. Experiment 2: Control versus IR main effect*



*Figure 2.4.2. Experiment 2: NP effect as a function of age group*  
\*  $p < .001$

*Table 2.4.2 Percentage of Participants showing NP Effects in Experiment 2*

Age group	% of NP Effects
5 - 6 yr olds	64%
8 - 9 yr olds	76%
11 - 12 yr olds	78%

### ***Error analysis***

Similar analyses were conducted for error scores. The between-subjects factor of age group (5 - 6 yr olds versus 8 - 9 yr olds versus 11 - 12 yr olds) was significant,  $F(2,147) = 6.62$ ;  $p < .002$ . Importantly, the within-subjects factor of priming condition (Control versus IR) was significant,  $F(1,147) = 10.01$ ;  $p < .002$ . Participants made more errors on IR trials than on Control trials. There was no significant interaction between priming condition and age group,  $F(2,147) < 1.0$ . Thus, the error results clearly corroborated the RT results and again there was no indication of a speed-accuracy trade off.

## **2.5 Discussion**

The significant NP effects obtained with Stroop stimuli offer further evidence suggesting that intact inhibitory mechanisms in a non-spatial, conceptually-based experimental context are operational in children as young as five and six. Experiment 2 has thus replicated the pattern of results obtained in Experiment 1 using very different stimuli. NP effects in children between the ages of five and 12 appear to generalize across experimental paradigms. The reported results also offer further support for the hypothesis suggesting that experimental manipulations designed to intensify "selection state" allow for the observation of significant NP levels in children.

The reported priming effects for Experiment 1 and 2 imply that NP effects in children are similar to those in adults. They reflect an inhibitory mechanism capable of working with a range of stimuli types. Levels of inhibition in children do not appear to be task and/or stimuli specific. In addition, Experiment 2 has further demonstrated that experimental manipulations concerning "selection state" may have important implications for the level of NP observed in children.

Sensitivity to variation in selection requirements on prime and probe trials appears to be heightened in children in comparison with adults. Preliminary support for this comes from the results reported by Tipper et al. (1989). While significant levels of NP were found with adults (19 - 21 years) within an experimental context which included Neutral and Repeated Ignored conditions, these results were not found for children (7 - 8 years). Conversely, experimental contexts such as those used in Experiments 1 and 2 of the current study, containing Control and IR conditions only, may promote the observation of significant NP levels in children.

### *2.5.1 Developmental Trends With The Stroop Effect*

Empirical research on the Stroop colour-word test in which participants name the ink colours of printed incongruent words has revealed certain developmental patterns. The Stroop effect, whereby covert colour word reading appears to be automatically initiated without intention despite attempts to avoid this by the subject, is one of the most cited examples of automaticity and uncontrollability (Tzelgov, Henik & Leiser, 1990). The interference effect is typically gauged by comparing latency of colour naming of neutral stimuli with latency of naming incongruent colour-word stimuli. However, this effect is not evident in children below reading age, and at its highest level in 7-year-olds, after which it decreases until the age of 17 - 19 and remains constant through middle adulthood (Comalli et al., 1962; Schiller, 1966).

A salient feature in the Stroop paradigm is the prepotent-alternative response dynamic. The prepotent tendency is to read the word while the alternative (correct) response is to identify the colour of the ink. Although word reading is a highly skilled and automatic process, the developmental patterns with the Stroop paradigm show that some control of this automatic processing is possible.

A reduction in Stroop interference should not be taken to mean that the distractor (colour word) was not processed as deeply in older children. For example, research by

Driver and Tipper (1989) found that distractors which did not interfere with response to concurrent semantically related targets still produced NP effects. Likewise, research undertaken by Mari-Beffa, Estevez, and Danziger (2000) investigating the Stroop effect within a NP paradigm found intact NP from the ignored prime colour word even when the Stroop effect had been eliminated through experimental modifications to the colour word. For example, research by Besner, Stolz, and Boutilier (1997) had demonstrated that when only a single letter of the colour word in a Stroop task is coloured as opposed to the whole word, the Stroop effect is eliminated, apparently implying that word processing is not an automatic process. However, Mari-Beffa et al. (2000) argued that the absence of a Stroop effect in Besner et al.'s task does not necessarily infer a lack of word processing; a proposition based on a review of the work by Driver and Tipper (1989). When Besner et al.'s (1997) version of the Stroop task was combined with a NP procedure so that the probe ink colour was related to the prime word, Mari-Beffa and colleagues observed significant NP effects. This indicated that the prime word was processed to the level of meaning.

Since NP is evident in children, and if NP functions as an index for the processing and inhibition of irrelevant stimuli, then increasing efficiency in the engagement of such an inhibitory mechanism may underlie the noted reduction in Stroop interference with age. Or, put another way, the appearance of NP within a Stroop paradigm may reflect an ability to exert control over automatic processing. Automatic processing and subsequent activation of the prime distractor (colour-word) can be overridden by inhibitory processes.

Alternatively, proficiency in reading skill may also determine the efficiency of the inhibitory process within a Stroop paradigm. Work by Tzelgov, Henik, and Leiser (1990) examining Stroop interference in bilingual participants found that the Stroop effect was substantially reduced in their native language in comparison to their second language. These findings suggest that language proficiency moderates the efficiency of

suppression processes. Applied to children, these findings would imply that as children's reading skills advance, Stroop interference should reduce. Therefore a reduction in the Stroop effect may be explained by an interrelation between inhibitory mechanisms and reading proficiency.

### ***2.5.2 Mechanisms Of Selective Attention***

A further relevant issue concerns Tipper et al.'s (1989) proposal outlined in Chapter 1, that repeated distractor facilitation could be explained by inhibitory and/or habituation mechanisms of attention. As results from their research regarding this proposal showed significant distractor repetition facilitation effects but no significant NP effects in children, Tipper et al. (1989) drew the conclusion that repeated distractor facilitation appeared to be due to the habituation of the orienting response and not to inhibition. This conclusion is not definitive, however, as both habituation and inhibition hypotheses concerning repeated distractor facilitation can make the same predictions. Because of this, ambiguous results regarding NP levels in children in Tipper et al.'s study provide little basis for their attributing repeated distractor facilitation to habituation. Indeed, it may be the case that an inhibitory mechanism underlies repeated distractor facilitation effects and without it the effect may not have been obtained. Put another way, it is not clear whether Tipper et al. (1989) produced evidence for habituation or inhibition of distractors. The observation of statistically significant NP effects from Experiments 1 and 2 in the current study allows for an alternative proposal regarding potential mechanisms underlying repeated distractor effects. Inhibition and habituation may both serve as explanations for repeated distractor facilitation. Furthermore, habituation and inhibition as mechanisms of attention are not necessarily, contrary to suggestions by Tipper et al. (1989), developmentally dissociated.

### **3.0 EXPERIMENT 3**

In order to further test the generalizability of the results reported thus far, a new task using vastly different stimuli was pursued. The present experiment examined potential short- and long-term implicit memory and NP effects for novel shapes (Neumann, 1999; Treisman & Deschepper, 1996). The issues of particular empirical interest were: (1) whether children would show significant NP effects for novel three-dimensional (3-D) stimuli; and if so, would these effects hold even for long durations. The investigations by Tipper et al. (1989) and Simone and McCormick (1999), as well as those undertaken thus far in this current study into NP in children, have used only familiar stimuli with pre-stored semantic or symbolic significance. This is, therefore, the first experiment designed to test for NP in children using objects with no pre-stored cognitive representation.

### ***3.1 NP as an Index of Implicit Memory: Effects with Novel Possible and Impossible 3-D Shapes***

#### ***3.1.1 Implicit Memory***

The term implicit memory refers to unintentional retrieval of previously acquired information, and is typically indexed through indirect memory tests not requiring recollection of specific prior episodes (Schacter, 1987). As an example, implicit memory may be inferred in tests such as word identification when participants show a facilitation in performance (often referred to as priming) that can be attributed to information acquired during a study condition (Jacoby, 1983). Recent research on selective attention has begun to explore the nature of perception and memory representations that are formed implicitly without conscious attention.

#### ***3.1.2 Implicit Memory for Novel Possible and Impossible Shapes***

In an influential series of studies on explicit and implicit memory, Schacter, Cooper, and Delaney (1990) assessed perceptual implicit memory for unfamiliar possible and impossible 3-D shapes using an object decision task. Their main concern was whether implicit memory depends on, or reflects the activation of, preexisting memory representations.

Participants in Schacter et al.'s (1990, Experiment 1) were given brief exposures to a variety of unfamiliar possible and impossible shapes in an initial encoding phase. Each shape in this phase appeared for five seconds. During this time participants were required to decide whether the displayed shape faced to the left or the right. In order to make this judgement participants needed to consider the shape as a unified global 3-D structure. Items representing possible shapes were constructed to have surfaces and edges that could potentially exist in the real world. Impossible objects were represented by constructions that contained subtle violations of edge, surface, or contour that would make it impossible for them to exist as actual three-dimensional structures.



After completing this initial encoding phase, participants took part in an object decision test. Here, subjects were given 100ms exposures to the drawings of the previously encountered shapes as well as to drawings of previously unseen unfamiliar possible and impossible shapes. For each of these displays, participants were required to decide whether the presented shape was possible or impossible. Accurate performance in this test required analysis of knowledge about global 3-D structure. According to Schacter et al. (1990), implicit memory could be inferred if object decision accuracy was higher for shapes previously seen than for those previously unseen.

Participants showed facilitatory priming via the object decision task for unfamiliar possible shapes previously presented in the encoding phase in comparison to unfamiliar possible shapes not previously seen. This effect implied that implicit memory is not dependent on preexisting memory representations. However, and most importantly for the present purposes, prior exposure to unfamiliar impossible 3-D shapes did not result in facilitatory priming effects. To Schacter et al. (1990), failure to achieve facilitatory priming effects for impossible 3-D shapes suggested that people have difficulty constructing a mental representation of such objects during initial encoding. Or put another way, global structural "impossibility" is difficult to represent internally.

### ***3.1.3 NP Effects with Novel Items and Possible and Impossible 3-D Shapes***

Recently, researchers such as Treisman and DeSchepper (1996) and Neumann (1999) have begun using the NP paradigm to probe implicit memory representations for unfamiliar items. DeSchepper and Treisman (1996) argue that NP has some advantages over facilitatory priming as a index for implicit memory. With NP effects, as the measure is one of impairment rather than facilitation, it may be assumed that it reflects unconscious involuntary processing and as such is not contaminated by any conscious use of explicit material.

Treisman and DeSchepper (1996, Experiment 1) investigated whether or not mental representations could be generated for novel stimuli which have no pre-stored mental representation. Treisman and DeSchepper classify object perception into visual types and visual tokens. Stored representations of familiar objects which are used in their identification and classification are termed as types. Tokens represent particular instances in object perception; they can be matched to a stored type for identification, however, if the object is entirely unfamiliar this cannot occur, yet the object is still perceived. The novel stimuli they used were two-dimensional (2-D) shapes that resembled the outlines of random jig-saw puzzle pieces. DeSchepper and Treisman (1996) suggested that NP effects for novel stimuli may provide insight into how a new token is set up. Their hypothesis was that if significant NP effects were obtained for novel stimuli with no existing types, this would imply that unfamiliar shapes can be registered as a token and stored implicitly without conscious attention.

Participants in Treisman and DeSchepper's negative priming task were presented with two novel overlapping outlined shapes, one green (target) and one red (distractor). Because the shapes had no names, a same-different matching task was used to index response latencies whereby participants had to decide whether the green shape matched an isolated white shape positioned slightly to the right of the overlapping shapes. All shapes in a display were presented simultaneously. In an IR trial the unattended red shape on the prime trial became the target on the probe trial. To provide a rigorous test of the above hypothesis, NP effects were compared for old familiarized shapes (10 novel shapes presented repeatedly as both attended and unattended stimuli in Control and IR trials) and for new shapes (120 new novel shapes, tested only once for any given participant; i.e., once as a prime distractor and once as a probe target in IR trials). Response times for IR trials using repeated stimuli were compared to Control trials using the same stimulus set. NP effects for shapes in IR trials using nonrepeated stimuli were gauged by comparison to Control trials containing new stimuli in both prime and probe displays.

DeSchepper and Treisman (1996) found significant NP effects for both familiarized and once presented novel shapes. This corroborated the implicit memory effects observed by Schacter et al. (1990) for unfamiliar stimuli and also extended these findings to a negative priming paradigm. Implicit memory exists for novel stimuli seen without attention. As the shapes used by DeSchepper and Treisman were unfamiliar meaningless nonsense shapes, they had no existing semantic category that could be activated. Accordingly, Treisman and DeSchepper concluded that because NP occurred for once presented, as well as for familiarized, nonsense shapes, inhibition is not limited to preexisting type nodes existing in a recognition network. This was consistent with Schacter et al.'s findings of facilitatory priming for unfamiliar possible 3-D shapes.

#### ***3.1.4 Short- and Long-Term NP Effects with Novel Items and Possible and Impossible 3-D Shapes***

Having established significant NP effects for novel nonsense shapes, Treisman and DeSchepper (1996) also conducted an additional series of experiments designed to investigate the duration of new object tokens. Two experiments employing a larger pool of novel stimuli and a different set of adult participants were run. These had lags of 1, 100, and 200 unrelated intervening trials between critical prime and probe displays. Surprisingly, significant and consistent NP effects were obtained for both short and long term lags. Results with long-term effects suggested representations of novel distractor stimuli formed during a single brief exposure are stored implicitly for long durations. To ensure these results reflected measures of implicit memory, participants were given a "catch trial" recognition test at the end of the experiment. This presented participants with a prime display followed immediately by a recognition test where five shapes were presented together on the same screen. Participants were required first to identify the distractor shape and then the target shape of the preceding prime display. Results were at chance for the distractor shape and slightly above chance for the target shape. Therefore implicit memory was inferred. Additional experiments by DeSchepper and Treisman (1996) investigating the durability of this long term NP effect found it to survive temporal delays of up to one month. According to the authors

this suggested that exposure to a novel item leaves in memory both a token representing its shape and (in IR trials) an "inhibitory action tag" attached to the irrelevant token indicating that it had been ignored.

Recent studies by Strayer and Grison (1999) have failed to find short-term NP for once presented familiar or unfamiliar items, however. In fact, whereas Treisman and DeSchepper (1996) reported NP effects with once presented stimuli, Strayer and Grison (1999) reported facilitatory effects for once presented stimuli. Moreover, these authors also suggest NP effects for both familiar and unfamiliar stimuli are contingent on stimulus repetition. This was demonstrated in a series of experiments using semantic stimuli. Strayer and Grison (1999, Experiment 1) had one half the of the IR couplets use words selected from a repeated stimulus ensemble and the remaining IR trials use words from a novel stimulus ensemble. Repeated words were those seen approximately 45 times during the experiment. These words were repeated in random order as targets and distractors. Novel words appeared only once as a distractor in the prime display and once as a target in the probe display. The Control for the novel words condition involved words that were presented only once, whereas in the IR condition a word appeared exactly twice as just described. Strayer and Grison found that priming was negative for the repeated stimuli but positive for the novel stimuli.

In a more direct comparison, Strayer and Grison (1999) conducted an additional experiment using unfamiliar items more similar to those used by DeSchepper and Treisman (1996). Again, however, they failed to replicate DeSchepper and Treisman's findings concerning NP effects for once presented stimuli. NP effects for these novel stimuli only emerged with stimulus repetition. According to Strayer and Grison (1999), these findings suggest that the appearance of NP relies on stimulus repetition. More specifically, inhibitory mechanisms are only required when distractor representations in IR prime trials are primed to a state of heightened activation as a consequence of prior repetition. Because of this, NP effects are not obtained for once presented stimuli.

Thus, Strayer and Grison contend that stimulus repetition is a necessary prerequisite for the engagement of the inhibitory mechanism underlying NP. Experiment 3 was designed in part to address this controversy.

Recent studies by Neumann (1999) question the generality of Strayer and Grison's (1999) findings, and instead provide further empirical support for Treisman and DeSchepper's (1996) results concerning short- and long-term NP with novel objects. Neumann (1999) used short- and long-term NP effects to provide a more exacting test of Schacter et al.'s (1990) conclusions regarding possible/impossible structure representation. Like DeSchepper and Treisman (1996), this was done through the use of a negative priming paradigm with a same-different matching task. However, unlike Treisman and DeSchepper, the novel stimuli used consisted of possible and impossible 3-D shapes similar to those used by Schacter et al. (1990). Counter to the claim by Schacter and his colleagues, if NP occurred with these impossible shapes it would demonstrate that mental representations of impossible 3-D shapes can be constructed and maintained.

Two experiments were conducted. The first of these examined short-term NP effects for possible and impossible shapes (i.e., priming of the target probe produced by the immediately preceding prime display) and used a small set of figures (eight possible and eight impossible) that were sampled repeatedly. NP effects were observed for both possible and impossible shapes. These results suggested that implicit memory does exist for impossible 3-D shapes. However, because this experiment used only a small set of shapes, the repeated presentation of these stimuli may have meant that mental representations of such shapes can be constructed as long as there are many opportunities to form such representations. Therefore, it was not entirely clear whether the NP levels gauged for impossible objects relied to some extent on this familiarization and repetition effect. A second experiment examined this issue.

The second experiment was designed to investigate long-term NP using a larger pool of shapes. Neumann (1999) argued that investigating long-term NP effects for impossible shapes presented once as a distractor in the prime display and once as a target in the probe display would provide a more rigorous test of Schacter et al.'s (1990) conclusions regarding impossible shapes. Unlike participants in Schacter et al.'s research who encountered each shape for five seconds during an initial encoding phase, participants in Neumann's task had only one brief encounter with each shape as an unattended stimulus (i.e., as a distractor to be ignored during the prime trial). Stimuli in Neumann's second experiment consisted of 120 new possible and 120 new impossible 3-D shapes. Long-term NP effects were gauged by having 98 unrelated displays appear between the critical prime and probe displays.

Results revealed significant long-term NP effects for both possible and impossible shapes. This suggested that representations of structurally impossible shapes seen during one brief exposure without attention can be constructed automatically and stored implicitly for long durations. Neumann's (1999) findings provide strong evidence against Schacter et al.'s (1990) conclusions regarding the inability of the human brain to create and store impossible 3-D shapes. In addition, these results contradicted Strayer and Grison's (1999) failure to find NP effects for once presented novel items while corroborating those found by DeSchepper and Treisman (1996) and extending them further by reproducing short- and long-term NP effects with more complex stimuli.

### **3.2 Experiment 3: Short- and Long-Term NP Effects for Novel Possible and Impossible 3-D Shapes**

The purpose of Experiment 3 was to test implicit memory for unfamiliar 3-D shapes in children via NP. As yet, no one has investigated either short- or long-term NP effects for novel stimuli in children. Obtaining significant short- and long-term NP effects for complex stimuli in children would not only support the respective findings of

DeSchepper and Treisman (1996) and Neumann (1999), but would also extend those findings to children and thus make an original contribution to the developmental literature.

This experiment used a task and procedure similar to the one described above by Neumann (1999). Issues regarding "selection state" strength were retained through the continued use of Control and IR trials only. In addition, stimuli presented on both prime and probe trials overlapped. Research by DeSchepper and Treisman (1991), reviewed in Fox (1995), regarding selection requirements in both prime and probe trials suggests that when perceptually distinct relevant objects are more difficult to disentangle from irrelevant objects, a greater magnitude of NP is likely to be observed.

### **3.2.1 Method**

#### ***Participants***

The same pool of individuals involved in the previous experiment were employed with the exception of the youngest age group (5 - 6 yr olds). Although approximately 25 children from the youngest age group (5 - 6 yr olds) were sampled in this task, most found it difficult to master or had difficulty maintaining attention throughout its duration. The youngest group was therefore eliminated from the present experiment.

#### ***Design***

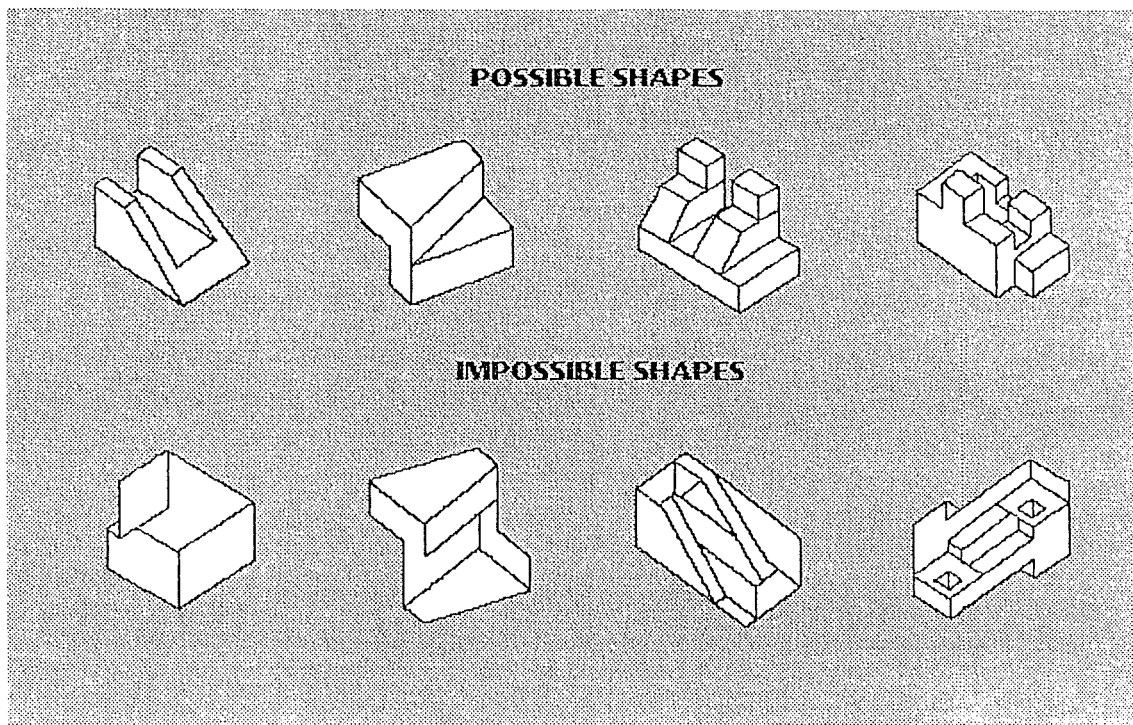
A mixed design was used. The between-subjects variable was age group (8 - 9 yr olds versus 11 - 12 yr olds). Within-subject variables were: priming condition (IR versus Control); shape type (possible versus impossible); and response combination (same-same, different-different, same-different, and different-same) which refers to the four possible response requirements within each prime-probe couplet. Time interval between the prime and probe trials was also manipulated. Because a small pool of

shapes was used repetitively in the immediate condition and a large pool of shapes was used non-repetitively in the lag condition, these two conditions were treated independently. There were no intervening displays between critical prime-probe couplets in the immediate condition. In the lag condition, however, there were 98 unrelated intervening displays between critical prime-probe couplets. This introduced approximately a 5 minute delay between a prime and its probe. The distribution of stimuli across participants and conditions in the experiment was counterbalanced. Control and IR trials were randomised throughout the experiment.

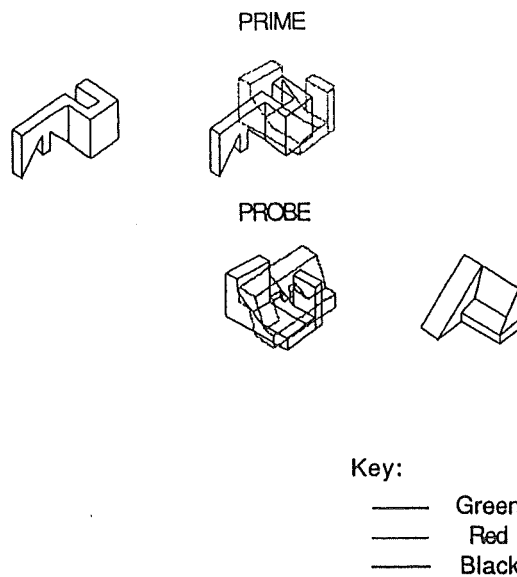
### *Apparatus and Stimuli*

A Power Macintosh 6200/75 computer and a 15 inch colour monitor were used to present stimuli. Participants responded by way of a response box with two buttons labelled "same" and "different". The stimuli included overlapping line drawings of novel possible and impossible 3-D shapes similar to those used in research by Schacter, Cooper, and Delaney (1990; see Figure 3.2.1.). These displays were organized into pairs consisting of a prime display followed by a probe display (see Figure 3.2.2). Included in each prime and probe display were an overlapping red non-target and green target shape centred on the screen, and a black comparison shape appearing randomly either to the right or the left of the overlapping shapes. All shapes were presented against a grainy white background. The red shape was offset from the green shape by about 25% appearing randomly to either the upper or lower left or upper or lower right. Where the contours of the overlapped shapes crossed, the green line occluded the red one. The distance between the outer edge of the nearest overlapping and comparison shapes was about 2.5 cm. The area of space occupied by the overlapping shapes ranged between 3 x 3 and 4 x 4 cm, and for the comparison shape between 2.5 x 2 and 3 x 3 cm. Shapes were positioned so that central points of the green target and black comparison shape fell upon an imaginary horizontal line bisecting the middle of the screen.





*Figure 3.2.1. Sample of possible and impossible 3-D shapes used in Experiment 3. Adopted from Neumann (1999).*



Example of a "Same-Different" Negative Priming pair with Possible shapes. The unattended red shape in the prime trial becomes the attended green shape in the probe trial.

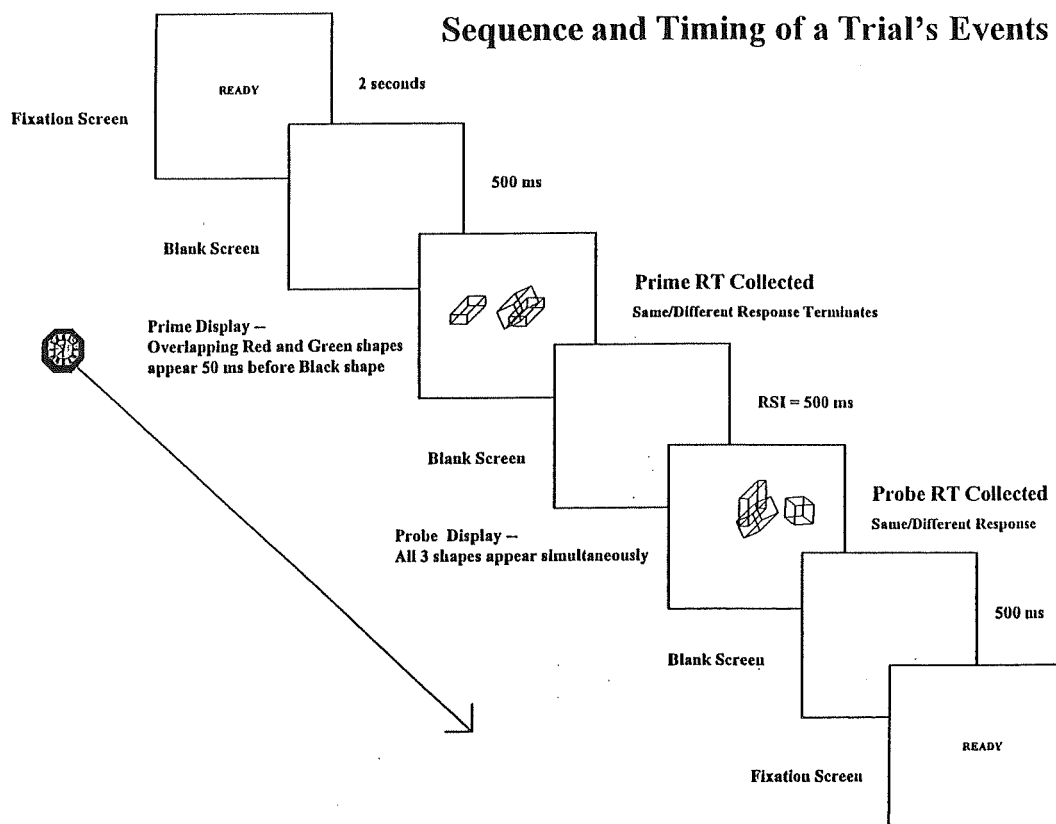
*Figure 3.2.2. Example of a "same-different" IR prime-probe trial used in Experiment 3. Adopted from Neumann (1999).*

In the immediate condition a small pool of objects comprising 16 possible and 16 impossible shapes was employed. A larger pool of 120 new possible and 120 new impossible shapes were used for the lag condition. No shape in any given prime or probe display for the lag condition matched any shape in the preceding, current, or subsequent trial (unless it was used in the IR condition). For both the immediate and lag conditions, prime-probe couplets involving possible shapes included only possible shapes and those involving impossible shapes included only impossible shapes.

### *Procedure*

Participants were individually tested in a dimly lit room in one session requiring approximately 40 minutes. All participants were informed that they would see one green and one red shape which overlapped and a black shape off to the right or left side on the computer screen. The red shape was described as being there to make the task more difficult, and participants were advised to ignore the red shape as best as they could. Participants were then verbally instructed that their task was to decide if the green target shape matched the black comparison shape. The experimenter demonstrated how to respond via the response box. Participants were required to press the "Same" button if they considered the shapes to match, and the "Different" button if they did not match. They were reminded a number of times to respond as fast as they possibly could, while keeping errors to a minimum. It was also pointed out that the correct response was required before the display would advance. Individuals were positioned approximately 60 cms from the screen and told to rest both hands on the response box while using the right index finger to control the button labelled "different" and the left for the button labelled "same". If a child expressed discomfort with this arrangement they were allowed to adopt their own method of responding (typically using one index finger for both buttons). The majority of participants in the younger age group (8 - 9 yr olds) adopted this alternative response mode while the majority of children in the older age group (11 - 12 yr olds) responded in the manner specified by the experimenter.

Each session began with a set of practice trials followed by 320 experimental trials divided into three blocks. Two short breaks were provided between the three experimental blocks. After each break, participants pressed the "Same" button when they were ready to begin. Each experimental trial began with a two-second fixation point followed by a 500ms blank screen prior to the prime display. The appearance of overlapping red and green shapes in the prime display occurred 50ms before the black comparison shape. The same/different response terminated the prime display which was followed by a 500ms RSI in which a blank screen appeared before the probe display. The overlapping red and green shapes and the black comparison shape appeared simultaneously in the probe display. The probe display was followed by a blank screen for 500ms before the next trial began (see Figure 3.2.3 below). The experimenter remained in the room at all times throughout each session to ensure that the participants remained engaged in the task. Reaction times and errors during prime and probe displays were automatically recorded through the computer software.



**Figure 3.2.3.** *Sequence and timing of a trial's events. Adopted from Neumann (1999).*

### 3.2.2 Results

#### *Scoring*

Prime and probe errors were recorded and included in the error analysis. Any errors committed on a prime trial meant that the corresponding probe RT score was excluded to avoid RTs that might include any adjustment time required by the participant due to the preceding faulty response. Extreme scores for Control and IR trials taking longer than five seconds for 8 - 9 yr olds and three seconds for 11 - 12 yr olds or less than 300 ms (for both) were excluded from RT analyses. Immediate condition analyses are treated first, followed by the lag condition. Means of median RTs and percentage of errors for the Control and IR trials for the immediate condition are shown in Table 3.2.1.

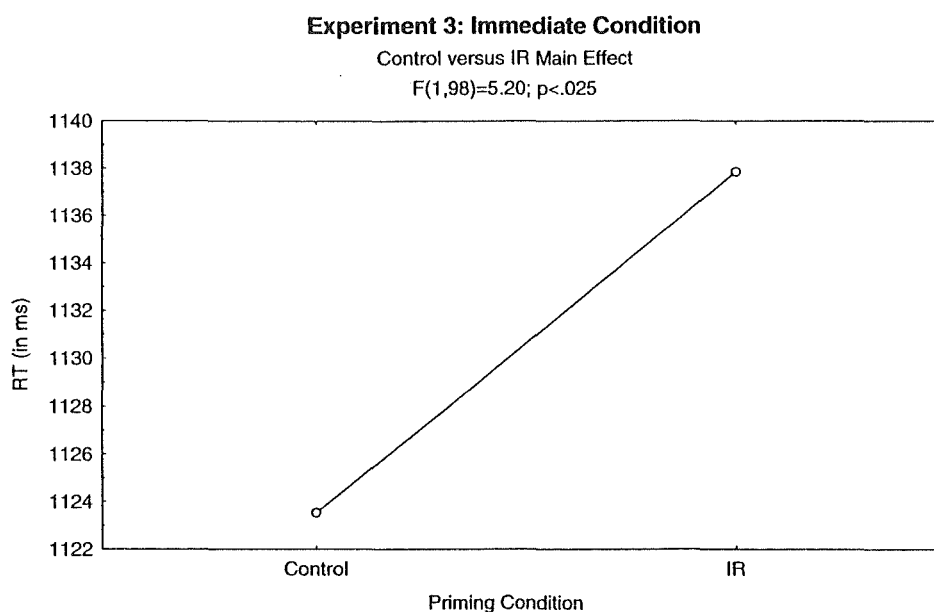
*Table 3.2.1 Means of Median Reaction Times (in Milliseconds) and Percentage of Errors for each Age Group as a Function of Priming Condition in the Immediate Condition in Experiment 3*

	8 - 9 yr olds	11 - 12 yr olds
Condition		
<u>Control</u>		
M	1298	949
SD	339	205
ER (%)	10.4	8.1
<u>IR</u>		
M	1319	956
SD	339	198
ER (%)	10.0	8.3

#### *Reaction Time Analysis: Immediate condition*

The data for the immediate condition RT were analysed using a mixed ANOVA. The between-subjects factor was age group (8 - 9 yr olds versus 11 - 12 yr olds). The within-subjects factors were: priming condition (Control versus IR); shape type (possible versus impossible); and response combination (same-same, different-

different, same-different, and different-same). The between-subjects factor of age group was significant,  $F(1,98) = 41.24$ ;  $p < .001$ , indicating that the 8 - 9 yr olds required significantly longer to respond. More critically, the within-subjects factor of priming condition (Control versus IR) was significant,  $F(1,98) = 5.20$ ;  $p < .025$ . Participants responded slower on the IR trials than on Control trials (see Figure 3.2.4.). The mean magnitude of the NP effect for 8 - 9 yr olds was 21 ms and 8 ms for the 11 - 12 yr olds. The interaction between priming condition and age group did not approach statistical significance,  $F(1,98) = 1.11$ ;  $p > .29$ . This suggested that the NP effect was similar for the two age groups and was unrelated to overall processing speed. The percentage of participants showing NP effects for each age group is shown in Table 3.2.2.



*Figure 3.2.4. Experiment 3 immediate condition: Control versus IR main effect.*

The within-subjects factor of shape type (possible versus impossible) was not significant,  $F(1,98) = 2.58$ ;  $p > .11$ . Likewise, the interaction between priming condition (Control versus IR) and shape type (possible versus impossible) did not approach statistical significance,  $F(1,98) = 1.25$ ;  $p > .26$ . Finally, there was no significant interaction between shape type and age group,  $F(1,98) = 1.60$ ;  $p > .21$ . No other higher-

order interactions were significant. Collectively these results suggested NP effects were similar for both possible and impossible shapes for 8 - 9 yr olds and 11 - 12 yr olds.

There was a significant effect for response combination (same-same, different-different, same-different, and different-same) which reflected the fact that it generally required longer to respond "different" than to respond "same". Response combination did not interact significantly with any other variable.

*Table 3.2.2 Percentage of Participants showing NP Effects in Experiment 3: Immediate Condition*

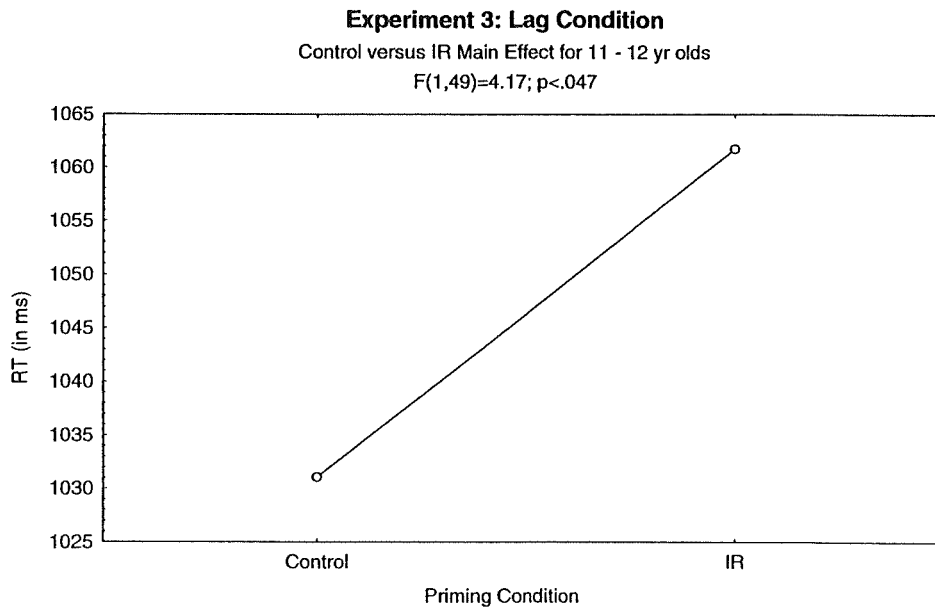
Age group	% of NP Effects
8 - 9 yr olds	62%
11 - 12 yr olds	68%

#### ***Reaction Time Analysis: Lag condition***

Similar analyses were conducted for median RTs in the lag condition. The between-subjects factor of age group (8 - 9 yr olds versus 11 - 12 yr olds) was significant,  $F(1,98) = 27.16$ ;  $p < .001$ , again suggesting that the younger group required longer to respond overall. The within-subjects factor of priming condition (Control versus IR) did not approach statistical significance,  $F(1,98) < 1.0$ . More importantly, however, there was a significant interaction between age group and priming condition,  $F(1,98) = 5.44$ ;  $p < .021$ . Additional analyses revealed that priming condition (Control versus IR) failed to reach statistical significance only for 8 - 9 yr olds,  $F(1,49) = 2.00$ ;  $p > .16$ . Statistical significance was attained for 11 - 12 yr olds,  $F(1,49) = 4.17$ ;  $p < .047$ . Participants in this age group responded significantly slower on the IR trials than on Control trials (see Figure 3.2.5.). Fifty eight percent of the 11 - 12 yr olds showed NP effects in the lag condition.

The interaction between priming condition (Control versus IR) and shape type (possible versus impossible) did not approach statistical significance,  $F(1,49) < 1.0$ . Thus it

appeared that NP effects for 11 - 12 yr olds were similar for both possible ( 27 ms) and impossible ( 34 ms) shapes.



*Figure 3.2.5. Experiment 3 lag condition 11 - 12 yr olds: Control versus IR main effect*

#### ***Error analysis for immediate and lag conditions***

Error scores for the immediate and lag conditions were submitted to similar analyses. For the immediate condition there was no significant difference in the rate of errors in the Control versus IR conditions,  $F(1,97) = 1.08, p >.20$ . Likewise, for the lag condition there was no significant difference in the rate of errors in the Control versus IR conditions,  $F(1,97) < 1.0$ . In fact, no error rate effects were significant in either the immediate or lag conditions. Thus the error data do not compromise the interpretation of the RT data. There did not appear to be a speed-accuracy trade off.

### 3.3 Discussion

Experiment 3 helps resolve several outstanding empirical questions about negative priming in general and more particularly in children. Findings of significant short-term NP effects with possible and impossible 3-D shapes for 8 - 9yr olds and 11 - 12 yr olds, and long-term NP effects for 11 - 12 yr olds replicate and extend the findings with adults by Neumann (1999). It also provides further empirical support for the research by DeSchepper and Treisman (1996) using a different set of novel stimuli. More specific implications arising from the present experiment are: 1) additional support is provided for both the existence of inhibitory capacity in children and for the generalizability of these effects across experimental paradigms; 2) structurally possible and impossible 3-D shapes can be mentally constructed and represented from the age of eight years; 3) representations of structurally possible and impossible 3-D shapes can be constructed and stored implicitly for long durations in 11 and 12 year old children; 4) stimulus repetition is not a necessary prerequisite for NP effects.

#### *3.3.1 Long-Term NP Effects*

Long-term NP effects with possible and impossible stimuli were found only for the 11 - 12 yr olds. There are three points of interest regarding this finding. First and foremost, it provides empirical support for the findings reported by DeSchepper and Treisman (1996) and Neumann (1999) regarding long-lived NP effects for novel stimuli. Despite being ignored, unattended shapes appear to leave a highly specific mental representation. And despite the fact that a multitude of shapes were presented for perceptual processing during the experiment, representations or tokens for unattended shapes in the prime trials of IR couplets in the lag condition were of sufficient detail to be differentiated from others in the set. This was clearly evidenced by the delay in response to the shapes when they were re-presented as target stimuli on probe trials, even after 98 intervening displays.



Second, although significant long-term NP effects were obtained for 11 - 12 yr olds these effects were not observed for 8 - 9 yr olds. These results may have important implications for future research concerning the development of mechanisms of attention and are intriguing in that they suggest that inhibitory tags associated with irrelevant stimuli may not be as durable before the age of 11 years.

Thirdly and finally, the current findings of long-term NP effects question the generality of Strayer and Grison's (1999) conclusions concerning the dependency of NP on stimulus repetition. Recall that Strayer and Grison argued that NP only emerges when prime distractors on IR trials have been primed to a state of heightened activation by appearing beforehand as a target at least a couple of times. It is only under such heightened competitiveness that they believe inhibitory processing of distractors is engaged. The findings from the current experiment have failed to support this hypothesis. Significant NP effects were obtained for unattended distractors with only one brief exposure in the lag condition.

It is unclear why Strayer and Grison failed to replicate the findings by DeSchepper and Treisman (1996) regarding NP for once presented stimuli given that these findings have now been replicated using much more complex stimuli by Neumann (1999) and the present experiment. One possibility may concern differences in the number of trials requiring selection in the respective research. Strayer and Grison used overlapping stimuli designed to be the same as DeSchepper and Treisman's, along with the identical same-different matching task. However, they only included 16 Control and 16 IR couplets in comparison to the approximately 60 Control and 60 IR trials included within DeSchepper and Treisman's (1996) briefest experiment. It may be that NP effects emerge only after a certain number of trials requiring selection so that expectations regarding processing demand are firmly established.

## 4.0 General Discussion

This study centred on three aims relevant to current issues in the developmental and NP literature: 1) to determine the existence of inhibitory processing in children as a mechanism of selective attention using a non-spatial, conceptually-based experimental design; 2) to investigate the generality of NP effects in varying age groups of children across a range of experimental paradigms; 3) to verify and extend the experimental outcomes of research by DeSchepper and Treisman (1996) and Neumann (1999) concerning short- and long-term NP effects for novel 2-D and 3-D stimuli, respectively. The starting point was an attempted reconciliation of the discrepancies between the findings of Tipper et al. (1989) and Simone and McCormick (1999) concerning the existence and appearance of NP effects in children. These two studies implied that: a) the existence of conceptual NP effects in children is questionable; and, b) NP effects in children may only emerge for designs with an inherent spatial or localization component.

Findings from the current study shed light on these issues. In particular, the experiments have consistently shown reliable and similar size conceptual NP effects across age groups for non-spatial, conceptually-based designs. It, therefore, appears that it is not necessary to use spatial or localization-based experimental designs in order to observe NP effects in young children. Because NP effects were of a similar magnitude for the three age groups, it suggests that the inhibitory mechanism responsible for producing conceptual NP is intact in young children. Additionally, NP effects were general, occurring for both differing stimuli and task demands. This study has also highlighted some specific determinants that may affect the appearance and magnitude of NP in children.

#### ***4.1 Implications for Inhibitory Processing and the Ability to Attend Selectively in Children***

The natural environment contains many objects that compete for attention. Because not all objects are relevant at any one time an ability to attend selectively is imperative to normal everyday function. If NP effects are taken to reflect, at least in part, the medium of this selection it should perhaps come as no surprise that children as young as five do show evidence for intact inhibitory capacity functioning to suppress irrelevant information. This makes good functional sense. It would seem that the ability of young children to survive in the natural world would be severely compromised without the ability to attend selectively.

The NP effects obtained for children in the three experiments of this study were quite general. Significant effects were obtained for both naming and same-different paradigms, vocal and manual responses, familiar and unfamiliar stimuli, and 3-D possible and impossible shapes. Such generalizability seems to reflect the operation of a common underlying inhibitory mechanism in children of varying ages.

Furthermore, obtaining long-term NP effects with nonrepeated unfamiliar stimuli has helped to resolve discrepancies in this area of research. First, implicit memory in children, as in adults, appears to exist for unfamiliar 3-D impossible shapes. A result which questions the validity of Schacter et al.'s (1990) conclusions concerning the inability of the human brain to construct and maintain representations of structurally impossible shapes. Second, long-lived NP effects with nonrepeated stimuli corroborate previous research by Treisman and DeSchepper (1996) and Neumann (1999). On the other hand, because significant NP effects were obtained for nonrepeated stimuli, no support was provided for Strayer and Grison's (1999) contention that NP effects are contingent on stimulus repetition. Interestingly, however, long-term NP effects were only found for the oldest age group. It is suggested that attempts be made to replicate these results as they may provide significant insight into the development of implicit memory.

One of the more subtle, but important, implications of the current study is that experimental manipulations concerning "selection state" may have an important bearing on the level (or even the presence) of NP observed in children. NP effects in children may be absent when selection difficulty is minimised and/or not consistently upheld across both Control and IR conditions. The present study perhaps allowed for the observation of significant NP effects in children by heightening and maintaining selection difficulty across all experimental trials. This was achieved by omitting any repeated distractor and neutral conditions, employing only the relevant IR and Control conditions, reducing spatial separation between target and distractor, downplaying the saliency of IR conditions, and using overlapping stimuli. Experimental manipulations affecting the strength or intensity of the "selection state" may provide a potential resolution to the discrepancy between the results of the current experiments and those reported by Tipper et al. (1989). These findings may have far-reaching consequences for research concerning cognitive development in children, because little mention is ever made regarding the role of inhibitory control mechanisms in this literature.

Finally, it is hoped that the colour blob task, designed and used in Experiment 1, may be useful for future research concerned with the development of NP effects in children. As this task allows for the observation of NP, it becomes possible to chart early development of inhibitory mechanisms in children below reading level. The colour-blob task may be seen as a valuable empirical tool for future investigations concerning NP in young children. Further supplementary use of this task may lie in its application for use with young children whose cognitive development lies outside normative trends. Comparisons between normative and sub-normative populations may reveal specific trends affiliated with NP effects and performance on other cognitive tasks.

#### ***4.2 Age and Inhibition***

The focus of this section is to review existing research on age-related impairments in cognitive performance in light of the current findings regarding NP effects in children. Research in the field of cognitive aging suggests attentional processing declines later in

life. For example, the performance of older adults on a range attentional tasks closely mimics trends shown by children in terms of increased susceptibility to distractor interference and impaired responding (i.e., Cohen, 1988; Comalli et al., 1962; Davis, Cohen, Gandy, Colombo, VanDusseldorp, Simolke, & Romano, 1990; Farkas & Hoyer, 1980).

Researchers such as Hasher, Stoltzfus, Zacks, and Rypma (1991) have hypothesised that the impairments in cognitive functioning evidenced in older adults, specifically those relating to the ability to selectively attend, may result from inefficient inhibitory processing. They used a NP task to assess inhibitory capabilities in younger and older adults. Intact NP effects were only obtained for younger adults thus suggesting inhibitory mechanisms decline with age, a finding supported by a number of other studies within the NP literature (e.g., Kane, Hasher, Stoltzfus, Zacks, & Connelly, 1994; Stoltzfus, Hasher, Zacks, Ulivi, & Goldstein, 1993; Tipper, 1991).

Recently, however, research has challenged these earlier findings. A number of studies examining possible age differences in NP have found intact NP effects for older adults (e.g., Hartley & Little, 2000; Kramer, Humphrey, Larish, Logan, & Strayer, 1994; Pesta & Sanders, 2000; Schooler, Neumann, Caplan, & Roberts, 1997; Sullivan, Faust, & Balota, 1995). These results imply that inhibitory processes in older adults are not impaired.

Likewise, the results from experiments reported within the current study suggest that inhibitory processing is intact in children, at least from the age of five years. Moreover, these effects appear to be of a general nature. Collectively, the evidence implies that inhibitory processes are intact and effective across the life-span.

Although inhibitory processes appear to be fully operational in children and older adults, it is undeniable that these age groups show delays in reaction time and larger

amounts of interference over a range of interference-sensitive tasks in comparison to younger adults. It is unclear why early and advanced age is associated with an impairment in certain measures of selective attention given that the inhibitory function in selection, as evidenced by NP is intact. What seems clear, however, is that this interference is overcome by the same inhibitory mechanism that is operational in young adults.

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## **6.0 APPENDICES**



## **Appendix Contents**

Appendix A	Parental consent form
Appendix B	Example of blob Control card used in Experiment 1
Appendix C	Example of blob IR card used in Experiment 1
Appendix D	Verbal instructions for Blob Colour-Naming Task
Appendix E	Experiment 1.2: Naming 11 Unique Colours Versus Naming Nine Unique Colours and One Duplicate Colour twice
Appendix F	Example of Stroop colour count (11 unique colours) card used in Experiment 1.2
Appendix G	Example of Stroop colour count (nine unique colours and one duplicate colour) card used in Experiment 1.2
Appendix H	Example of Stroop Control card used in Experiment 2
Appendix I	Example of Stroop IR card used in Experiment 2
Appendix J	Verbal instructions for the Stroop Colour-Naming Task
Appendix K	Certificate of Participation awarded to participants
Appendix L	Logic Behind the Sequence of the Administration of Experiments

## **Appendix A**

### **Parental consent form**

## **Consent to Participate in a Research Study**

Dear Parent,

Your child is invited to take part in a research study which investigates selective attention in children. It is important that you read and understand several general principles that apply to all children who take part in this study: (a) taking part in the study is entirely voluntary; (b) personal benefit may not result from taking part in this study, but knowledge may be gained that will benefit others; (c) if your child wishes to withdraw from participation or you wish to withdraw your child's participation, your child or you may do so at any time. The nature of the study, the risks, inconveniences, and other pertinent information about the study are discussed below.

### **Purpose**

The purpose of this study is to investigate how children attend to, perceive, and remember information. Your child will be asked to do tasks that involve seeing verbal or pictorial materials and making timed responses to them. Children will be asked to do the following:

- 1) detect and respond to pictures or words that are presented relatively quickly
- 2) name the ink colours of various visually presented words
- 3) make "same" vs "different" matching judgements about pairs of novel 3-dimensional objects

### **Inconvenience, Risk, and Confidentiality**

Your child will be required to participate in one 1/2 hour and two 15 minute sessions. These will be three separate sessions and held on different days in a classroom at your child's school during school hours. After completing these sessions your child will receive a Certificate of Participation. It is expected that your child will not find participation in this study unpleasant, and I cannot foresee any possible risk your child may encounter because of their participation. If, however, you wish to withdraw your child or your child wishes to withdraw from participation, you or your child may do so at any time. I would like you to know that your child's data will be held in the strictest confidence. No names or individual identification will be used in publications that may arise as a result of this research. Only the principal investigators will have access to the names of the participants and their data.

This study is being carried out as research for a thesis for the degree of M.Sc. by V.E.Pritchard under the supervision of Dr E.Neumann, who can be contacted at the Psychology Department, University of Canterbury (phone 364-2987 ext. 6964). He will be pleased to discuss any concerns you may have about your child's participation in this study.

This study has been reviewed by the University of Canterbury Human Ethics Committee.

**I have read and understood the description of the above named project. On this basis, I agree to allow my child to participate as a subject in the project, and I consent to the publication of the results of the project with the understanding that anonymity will be preserved. I understand also that at any time I may withdraw my child from the project.**

I agree to allow my child, \_\_\_\_\_ to participate in the study described above.

**Signed:** \_\_\_\_\_ **Date:** \_\_\_\_\_

**Please Print:**

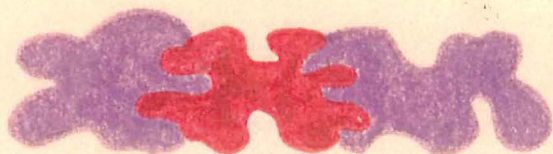
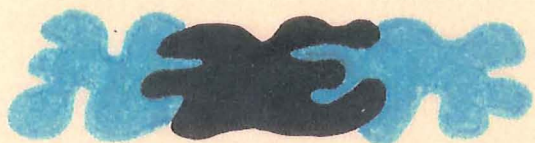
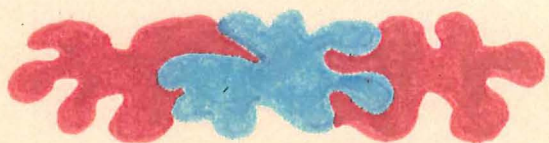
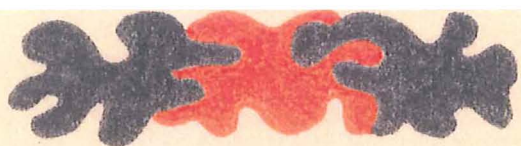
Child's Full name: \_\_\_\_\_

Child's Birth Date: \_\_\_\_\_

## **Appendix B**

### **Example of blob Control card used in Experiment 1**

Designed by the author. Reduction approximately 20%. Colours in reproduction vary from those in original.

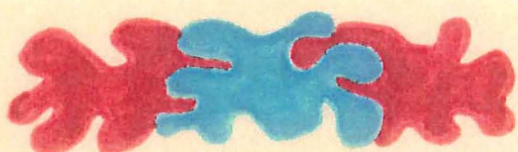


## **Appendix C**

### **Example of blob IR card used in Experiment 1**

Designed by the author. Reduction approximately 20%. Colours in reproduction vary from those in original.





## **Appendix D**

### **Verbal instructions for Blob Colour-Naming Task**



## **Verbal instructions for the colour-blob task**

This card has blobs in different colours printed on it and these are in groups of three from the top to the bottom of the card (participant is shown one of the practice cards and these features are pointed out). I want you to name the colour of each middle blob from the top to the bottom of this card and on other cards like this one that I am going to show you. Try to name the colours as fast as you can without making any mistakes. This is a test to see how quickly you can see and name colours. I will be timing you with a stop watch. Before we start the real test you can practice with three cards which I will give you now. When I say "Go!" I will lift this (a blank card covering the experimental card) and you start straight away to name the colour of each middle blob that you see on the card underneath. Remember to start at the top of the card (participant is then given the three practice cards and on completion is allowed to see their times). OK now that you have had some practice we will start the real test (participant is then given the set of experimental cards).

## **Appendix E**

### **Experiment 1.2: Naming 11 Unique Colours Versus Naming Nine Unique Colours and One Duplicate Colour twice**

This supplementary experiment was devised to address a potential confound in the design of Experiments 1 and 2. More specifically, target colours for the first prime-probe couplet on each of the IR cards were unrelated in order to help counter the saliency of the IR condition. It was hoped that this would make it less likely for participants to notice that the nontarget distractor becomes the subsequent target for the remaining stimuli on these cards. However, this precautionary measure meant that, contrary to Control cards which had 11 different target colours, IR cards had nine different target colours and one duplicate target colour. Thus, although the total number of target colours to be named was the same (i.e., 11) for both the Control and IR cards, the IR cards contained one target colour that was repeated. Because of this difference between the conditions (in addition to the intended manipulation) it was deemed important to rule out the possibility that the repetition of one of the colours in the IR condition could have caused the IR impairment. To resolve this matter empirically, the following method was employed.

#### **1.2.1 Method**

##### ***Participants***

Twenty participants from each of the three age groups used in Experiments 1, 2, and 3 were selected at random for inclusion.

##### ***Design***

A standard integrated colour-word Stroop procedure was used to examine the impact of naming 11 colours once versus naming nine colours once and one duplicate colour twice on response time. As with Experiment 1, a mixed design was employed. The between-subjects factor was age group (5 - 6 yr olds versus 8 - 9 yr olds versus 11 - 12

yr olds). The within-subjects factor was Stroop colour count condition (naming 11 unique colours versus naming nine unique colours and one duplicate colour that appeared twice). The distribution of stimuli across participants and conditions was counterbalanced.

### *Apparatus and Stimuli*

Experimental modifications notwithstanding, the stimuli used were similar to those used in Experiment 2. There were four cards per colour count condition as well as one practice card (11 unique colours). Examples of these conditions are displayed in Appendices F and G.

### *Procedure*

Before the administration of test trials one practice card (11 unique colours) was given. Otherwise, the procedure followed that used in Experiment 1

## **1.2.2 Results**

Response time (RT) and error data were subjected to a mixed ANOVA. For each participant a mean RT was computed from the four cards representing naming 11 unique colours and the four cards representing naming nine unique colours and one duplicate colour. Mean RTs for both conditions are shown in Table 1.2.1. There was a significant main effect of age group on RTs,  $F(2,54) = 27.80$ ;  $p < .001$ . More importantly, RTs differed for the different Stroop colour count conditions. Naming nine colours and one duplicate colour twice was significantly faster than naming 11 colours,  $F(1,54) = 20.08$ ;  $p < .001$ . This suggests that, if anything, there may have been an underestimation of the negative priming effects reported in Experiments 1 and 2. The interaction between age group and condition did not quite reach statistical significance,  $F(2,54) = 2.97$ ;  $p > .06$ . In addition, there was no evidence speed-accuracy trade off.

*Table 1.2.1. Mean Reaction Times (in Milliseconds) for each Age Group as a function of Stroop Colour Count Condition in Experiment 1.2*

	5 - 6 yr olds	8 - 9 yr olds	11 - 12 yr olds
Condition			
<u>naming 11 unique colours</u>			
M	21097	13479	12353
SD	5180	2298	3617
<u>naming nine unique colours and one duplicate colour twice</u>			
M	20155	12939	12163
SD	4952	2524	3190

## **Appendix F**

### **Example of Stroop colour count (11 unique colours) card used in Experiment 1.2**

Reduction approximately 10%. Colours in reproduction vary from those in original.

**BLACK**

**ORANGE**

**WHITE**

**RED**

**GREEN**

**GRAY**

**PURPLE**

**PINK**

**BROWN**

**YELLOW**

**GREEN**

## **Appendix G**

### **Example of Stroop colour count (nine unique colours and one duplicate colour) card used in Experiment 1.2**

Reduction approximately 10%. Colours in reproduction vary from those in original.



**PINK**

**WHITE**

**BLACK**

**ORANGE**

**BLUE**

**RED**

**GRAY**

**BROWN**

**GREEN**

**YELLOW**

**PURPLE**



## **Appendix H**

### **Example of Stroop Control card used in Experiment 2**

Reduction approximately 10%. Colours in reproduction vary from those in original.

**YELLOW**

**BLUE**

**GREEN**

**PURPLE**

**BROWN**

**RED**

**BLACK**

**ORANGE**

**WHITE**

**PINK**

**GRAY**

## **Appendix H**

### **Example of Stroop IR card used in Experiment 2**

Reduction approximately 10%. Colours in reproduction vary from those in original.



**BLACK**

**PURPLE**

**ORANGE**

**GREEN**

**BROWN**

**WHITE**

**RED**

**GRAY**

**PINK**

**YELLOW**

**BLUE**

## **Appendix J**

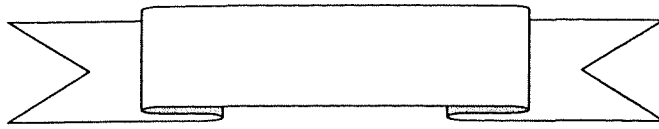
### **Verbal instructions for the Stroop Colour-Naming Task**

## **Verbal instructions for the Stroop task**

This card has several colour words written in different coloured inks (participant is shown one of the practice cards). I want you to name the colour of the ink each word is written in from the top to the bottom of this card and some others like this one that I will be showing you. Try and name the different colours of the ink as fast as you can without making any mistakes. This is a test to find out how fast you can see and name colours on a card. I will be timing you with a stopwatch. Before we start the real test you can practice with three cards which I will give you now. When I say "Go!" I will lift this (a blank card covering the experimental card) and you start straight away to name the colour of the ink that each word is written in from the top to the bottom of the card that you see underneath. Do this as fast as you can, but try hard not to make any mistakes. (participant completes three practice cards and is allowed to see their times before the commencement of the experiment). OK, now that you have had some practice we will start the real test (participant is now given the set of experimental cards).

## **Appendix K**

### **Certificate of Participation awarded to participants**



# Young Scientist Award



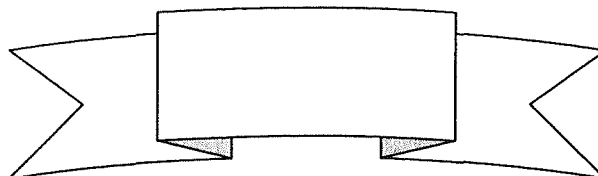
## Certificate of Participation

**This is to certify that** \_\_\_\_\_

**Participated in a research project for the University of Canterbury**

**Signed** \_\_\_\_\_

**Date** \_\_\_\_\_





## **Appendix L**

### **Logic Behind the Sequence of the Administration of Experiments**

Experiments were administered in the following order:

1) Short-term and Long-term NP effects for novel and possible and impossible shapes. It was suggested that children may find this particular task more stimulating and interesting than either the Stroop colour-naming task or the colour-blob task. Conducting this experiment first was likely to help sustain interest in the remaining experiments.

2) It was proposed that the saliency of the IR condition (especially for the older children) may be more evident in the colour-blob task where, unlike the Stroop colour-naming task, the stimulus dimension would not be integrated within the same perceptual object. Therefore all participants from all age groups were allocated the Stroop colour-naming experiment as their second task and the colour-blob experiment as their third in order to avoid possible contamination effects resulting from IR awareness.